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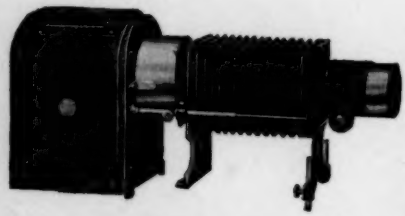

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SCHOOL SCIENCE AND MATHEMATICS

VOL. XVII, No. 5 MAY, 1917 WHOLE No. 142

SCIENCE IN THE SECONDARY SCHOOLS.[1]

BY R. A. MILLIKAN,
University of Chicago.

I have been asked by your committee to come here to speak upon the science situation in the secondary schools. Although my time and my energies in these latter years have been going more and more into research activities, so that it would be more than presumptuous for me to pose as an authority in education before those of whom it is more fitting that I should be the pupil, yet I have never ceased to be an interested, and I hope a thoughtful, observer of conditions and tendencies in this field. I am glad of an opportunity, therefore, to present to you some of my individual conclusions, and I am especially glad to be able to address principals and superintendents as well as science teachers, for the problem of the organization of the science instruction in the secondary schools seems to me to be one of the most important and at the same time most inviting problems in modern American education. It is important because science is the taproot of the tree of human progress. It is inviting because the present situation is obviously and admittedly bad, and practically nothing has yet been done toward its improvement. The opportunity is large, and it is the opportunity of the makers of the curricula even more than of the teachers of science.

Let me briefly justify those two statements. Differ as we may with Herbert Spencer's contention that science is practically the only basis of an education which is worth while—and no one would be readier than I to protest against such a pronouncement, for surely man's most fundamental interests are in the things of the spirit rather than in those of matter, in man rather than nature—yet it remains an indisputable fact that our civilization differs from, and excels, the civilizations which have preceded, chiefly be-

[1] An address read before the Lake Superior Teachers' Association, September 13, 1916.

cause of our scientific discoveries and their applications. There is no gainsaying the fact that the external conditions under which man lives his life here on earth have been more completely revolutionized within the past hundred years by the two scientific agencies of steam and electricity, with all that they mean, than in all preceding ages of recorded history put together. And if our spiritual and intellectual life excels that of the Greeks, is it not chiefly at least because of the new basis for thought which science has given to it?

And when we look away from the past and toward the future, can there be the silghtest doubt that our ability as a nation to keep in the forefront of human progress is going to be very nearly proportional to our success in mastering nature's laws and in applying them in our industries and our commerce? This is what has determined national greatness in the past century, and it is what, in all human probability, will determine it in the next. Whether it be in the struggles of peace or of war, it is in the long run the nation which knows which wins. And the nation which knows not is doomed. England's industrial supremacy has rested upon what? Upon Watt and Faraday. It was no accident that these were Britons. Britain is because these men and others like them were. Germany's recent commercial prosperity has come from what? Largely from her chemical Ph. D.'s. Without these chemists and their power to get nitrogen from the air, Germany in this war would long since have gone under. We as a people have had some scientific successes, but we must have many more if we are even to survive. I am proud to be able to say that the great science and the great art of speech transmission, to cite one example, is wholly American. There is not a foreign thread anywhere in the fabric of its development. It was conceived independently by the two Americans, Bell and Gray, immensely extended by Pupin with his loading coils, and the chapter has now been closed in a sense by the practically perfect transmission of undistorted speech without wires a third of the way around the earth by a group of American Ph. D.'s and engineers, three or four of whom, I am proud to say, have taken their degrees at the University of Chicago. This is a great achievement, and one which augurs well for our future, but it is not enough to secure it. Our national prosperity, yes, our national life itself, depends upon our further success in stimulating and rendering effective scientific and industrial research, and this in turn depends upon the appreciation and fostering of science by the king of our great land—the *common peo-*

ple. And where are they going to get that appreciation and that willingness to foster, save in the public schools?

So much in justification of my first assertion as to the value and necessity of a fine and full course in science in our public schools to every American youth to whom we can possibly give it.

Turn now to my second statement. The preesnt science situation in our high schools is bad, not, I think, because the science teaching itself is hopelessly poor, as a certain group of extremists who are urging the complete reconstruction both of the method and content of science instruction would have us think, but bad chiefly, if not solely, because the average high school pupil is actually getting a pitiably small fraction of the instruction in science to which he has a right and which he ought to have. About this fact there can be no question. It is brought out in every address on the science situation. The reports of the Commissioner of Education, showing that the percentage of students taking physics and chemistry, for example, in the high school, has decreased since 1890 from some thirty-three to about twenty-one per cent, is quoted so often that any speech which doesn't include these figures has come to taste to us like unsalted butter.

This report reveals a situation which we must all agree demands some study and a rational explanation. It does not mean necessarily that physics and chemistry have been badly taught or are uninteresting subjects. It means just exactly what it says, namely, that the high schools are not now sending as large a percentage of their total registrations into the classes in physics and chemistry as they sent in 1890. But we do not need to go to the Commissioner of Education to discover that the average student is not now getting nearly as much science as he ought to get. Look around and ask how many high school graduates have as much as one short year of each of the three fundamental subjects—biology, physics, and chemistry—every one of them a subject of which anyone who is to be in any way educated or to understand at all the mainsprings of twentieth century civilization must have some knowledge. I made an inquiry last year in what I suppose is a typical city high school, and found that the average graduate of this school had had about 1¾ units of science, all told. Prof. John G. Coulter says in a recent article: "I have found in a number of important high schools that the percentage of graduates having had no biology at all except the legal requirement of human physiology, runs as high as eighty-five, and it is quite common for it to run well above fifty—and this percentage of bio-

logical negligence is rising rather than falling. Recently it has been brought out in connection with studies of Illinois high schools that schools under two hundred in enrollment commonly require plant and animal studies in the second year. The limited number of courses offered necessitates greater uniformity of individual programs, and nearly all graduates get three years of natural science. But in schools beyond two hundred in enrollment, having an increased differentiation of program, a very different condition obtains. The second year of science becomes elective, with the consequence that usually more than half the pupils are deflected from it. It is in such schools that large majorities of seniors are found that have had no biological work in their programs."

In the University of Chicago, we get a group of about fifty each year who want *beginning* physics. How many more of the entering students have gone through the high school without taking physics I do not know. But these illustrations are enough to show that great numbers of our high school graduates do not get in the high school course anything like as much science as is needed for any sort of just appreciation of the role which science is playing in modern life—to say nothing of catching something of the scientific spirit. I have recently given[2] reasons for the belief that the average American high school graduate has not had half as much science as the corresponding student in practically every country in Europe. This is a situation which everyone, no matter what his own special interest may be, or what educational theories he may hold, will agree is unfortunate.

Now, what is the cause and what the remedy? The common assumption is that the cause lies in the fact that the pupils are not interested in science as it is taught. Hence, the doctors are bringing up all sorts of sugar-coated pills, which are guaranteed to be palatable, whether efficacious or not. One says: Drop out a formal physics course entirely, and slip in the principles of physics while the children are running their toy motors or their automobiles. I shall call this remedy "toy science," and I use the term merely to describe, not to derogate. Another labels his remedy "project science," and argues that, while the pupils are figuratively swallowing a delightful tennis game, it is possible, unknown to them, to slip in a spoonful or two of the wholesome castor oil of physics. A third scrambles all the sciences into a delicious potpourri, and calls it "general science."

[2] SCHOOL SCIENCE AND MATHEMATICS, Vol. XVI, 193, 1916.

All of these remedies are being urged *on the assumption that the difficulty is that the students are not interested in the sciences as taught, and that these reforms will stimulate their interest.* Yet the most cursory examination shows that the diagnosis is completely erroneous, and the remedy, presumably, correspondingly inappropriate. Take the Commissioner of Education's figures between 1890 and 1910. Will anyone who has been a month in any high school seriously urge that the relative interest in the subjects of Latin and physics is measured by the sixty per cent increase in the enrollment in Latin and the thirty-five per cent decrease in the enrollment in physics? Again, look at Professor Coulter's facts, for they are most significant. In schools under two hundred in Illinois, the students still get on the average three units of science. It is in the large schools, where the instruction is presumably best, that eighty per cent in some schools get no biology at all. Professor Coulter attributes the change simply to a change in the organization of the curriculum. In other words, it is a matter merely of school administration, not of interest at all. That the period of decline in registrations in science coincides exactly with the tremendous expansion of the American high school in numbers and in curriculum is the strongest indication of the correctness of Professor Coulter's analysis.

But we do not need longer to indulge in probable explanations, for there have recently been made a number of statistical studies on the pupils' interest in their studies. I reported some last year, in which the liking of the students for their science was high, but the total amount of science taken was very low. In no single case which I have seen reported in connection with these investigations has the student interest in the science courses been found to be low as compared with their interest in the other studies of the curriculum.

In my judgment, the decline in the percentage enrollment in science courses since 1890 has been due practically entirely to three causes, no one of which has anything to do with interest. First, in that period we who have had the making of the curricula —and "we" means the teachers of physics and chemistry more than anybody else—have made the woeful blunder of crowding over the sciences into the last years of the high school course, where the enrollment itself is small, and where from pedagogical reasons alone the sciences should not be. Second, the expanding of the curriculum and the consequent *subject pressure* have crowded out the sciences because they have been put up in tabloid

form instead of being made a sequence and welded together into a systematic and thoroughgoing course, as is mathematics or the languages, and hence they have been most easily pushed off the educational platter. Third, the dropping by the colleges between 1890 and 1910 of the specific entrance requirement of physics and the loosening of the hold of college entrance requirements on the high school program, both commendable moves, resulted in the abolition in the high schools of any specific science requirement for all students.

These causes are fully adequate, without reference to the matter of interest, to explain the change in the science situation in the schools, and any program which is urged primarily to make the science work more interesting doesn't hit the seat of the trouble.

What, then, is the remedy? It is suggested at once by the facts. But just a word, first, about the commonly suggested remedies, viz., "toy science," "project science," and "general science," all of which have the interest motif.

I want to express my unqualified indorsement of "toy science" for boys eight, nine, or even ten years old. I use it with my own boys and know from experience its values and its limitations. Playing with dynamos and motors, steam engines, and other things "that go" has proved the finest possible exercise for the children whom I have closely watched, at the age at which they are content with the most superficial explanations, or with none at all, and are interested primarily in what levers to turn to get the desired "go." Indeed, I think this is what our grade science is going to be, so far as the physical part of it is concerned, if we ever get it developed, but the boy of twelve or more needs and wants something bigger and better than that—some discussion of more fundamental causes than levers and valves. He wants the beginnings at least of a thorough and systematic course in science, as practical as you please, but with fundamental principles presented and discussed to some extent at least. The weakness of the "toy science" method for older pupils is admirably shown in an article on "High School Science and the Electrical Trades," by B. W. Kelly in a current number of this journal.

As to so-called "project science," it is as yet merely a name which has been given no definite and intelligible definition. Any well-taught course in physics or biology consists merely in working out a series of carefully chosen projects, and if this is what it means we will all indorse it heartily. The articles I have read upon it lead me, however, to relate it closely to "toy science," but

it isn't at present a well-enough defined or distinct enough movement to justify discussion.

Not so, however, with "general science." This has been put into textbook form, and we can get our definition by taking a composite photograph of the texts themselves. So defined, I think it is entirely fair to say that it consists of the easier and more entertaining parts of the special sciences thrown together into a book for use in the first year of the high school. That such a course can be made exceedingly interesting wherever taught, I have not the slightest doubt. So can any one of the special sciences. But with the curriculum already overcrowded, where must this new subject find its place? Anyone who, like myself, has tried to plan a full high school course for a boy and found the subject pressure so great that he cannot in any way find place for more than three units of science cannot for a moment fail to see that "general science" must be simply a substitute for either biology, or physics, or chemistry. Some of its advocates urge that this is not so. But either it must be so, or else it displaces something other than science. In that case that something can presumably just as little be spared as science, and, further, the student who takes "general science" and then all the individual constituent sciences has wasted one year of his time, since the whole of the content of "general science" is taught much more thoroughly and can also be taught just as interestingly in the individual sciences. On the other hand, if the "general science" replaces either biology, or physics, or chemistry, I have yet to find anybody who does not regard the substitution as most unfortunate. Certain it is that the "general science" must displace something—whether that is to be science or something else is possibly as yet uncertain, though from a priori considerations it seems well-nigh certain that it will be science. The committee of which Professor Caldwell is Chairman, and which reported[3] last spring on the "general science" situation, had obtained data upon this point from but four schools—much too small a number to make a valid generalization possible—but in these four schools the expected results had happened, namely, since the introduction of "general science" the percentage of total registrations in science, including "general science," had increased slightly, namely, from 68.8 per cent to 71.4 per cent—any other science brought down to the first year and required in some of the schools would have obviously produced the same results—while the registrations in other sciences had shown, in the words

[3] SCHOOL SCIENCE AND MATHEMATICS, Vol. XVI, 397, 1916.

of the committee, a "slight reduction." A study of the figures themselves, however, shows a much more ominous situation, for in the three schools in which alone a comparison is possible the fundamental sciences listed under the heads, "General Biology," "Botany," "Zoology," "Physics" and "Chemistry" show *the appalling* rather than *the slight* reduction of from fifty per cent to thirty per cent since the advent in these schools of the general science course.

From whatever point of view we look at it, the "general science" course introduced into the curriculum *along with the individual sciences* represents a woeful educational and economic waste for those students who take the full high school course, and it is these students alone who are under discussion in the present address. The two methods simply will not mix. The scrambling of the sciences in the early years of the course and unscrambling of them in the later is like a new patch on an old garment. It is wrong in principle and pernicious in practice. The only possible alternatives are to present the whole high school science course in the scrambled form, or else to scramble none of it. As to the former plan, it has not thus far been suggested, and if it were I should not expect it to be carried out, if for no other reason, because it requires planning *on a large and comprehensive scale, with careful consideration of the interrelations of subjects,* and our American method in general has been to ignore these interrelations and slip in detached courses *which are administratively easy to handle.*

My own plan, and here I come to what seems to me to be the remedy for the existing situation, is not to scramble the sciences at all, at least so far as a text is concerned, but, first, to let the student begin a definite systematic course in science the year he enters the high school, and a course the end of which he will be given to understand is at least two or three years ahead. In a word, I would have done with the pellet form of science instruction. I anticipate no difficulty in getting students to enter such a course. Indeed, every principal knows that his advice determines quite largely the average student's so-called choices.

Second, as to the nature of that course. I suggested last year that to gain the only advantage claimed by "general science" aside from interest, namely, that of correlation between the sciences, and at the same time to put the fundamental sciences, biology, physics, and chemistry, upon an exact equality, these three sciences be taught in parallel, say, each two hours a week throughout the first three years. This is essentially the plan followed

throughout the whole of Europe, save that physics gets there a much larger share of the total time. This plan presents no difficulties whatever *beyond administrative ones.* If these are thought too great, then I would teach the physics and biology in parallel throughout the first two years, one of them taking two hours one week and three the next, and the other three hours the first week and two the next. The chemistry could then follow in the third year. If this still presented too many administrative troubles, then I would offer a three-year consecutive course, with biology in the first year, physics in the second, and chemistry in the third.

All of these plans accomplish two things—first, they start the pupil when he enters the high school upon a course in the three fundamental sciences, which is understood to be of three years' duration. Second, they push all the sciences at least a year farther down in the high school course than they are now. Both of these changes will increase largely the amount of science taken by the average pupil, and both of them are highly desirable from a pedagogical as well as from a patriotic viewpoint. It is perhaps true that twenty years ago we did not have courses in the individual sciences which were suitable for use in the early years of the high school, but we have them now. In St. Louis the physics is largely taught now in the second year. Having long thought that physics ought to come earlier, I last year put my twelve-year-old boy, who was just entering the high school, into the third-year physics class. The experiment was in every particular a success. In Europe the boys all go into physics, and our sort of physics, too, at the age of twelve or thirteen years.

I stated at the outset that I was glad to have you principals and superintendents before me because the problem of improving the science output of our high school is largely one of organization of the curriculum and school administration. Nevertheless, the fault has been partly that of us teachers, for the pushing off of the sciences to the last years of the course has been permitted, if not urged, by us. Further, the initiative to reform must obviously come from us, who are most interested in the sciences, and who know best the situation. I think principals and superintendents will give us their cooperation if we will but present a definite and constructive program. Some days ago I heard Mr. Melville Stone, the originator of the Associated Press, say that America had shown matchless genius in everything *except organization.* In that she had been lamentably weak. In no place has she been weaker than in the organization of the science instruction in the secondary schools, and it is high time that a change were made.

SUGGESTIONS AS TO FIELD AND LABORATORY INSTRUCTION IN THE BEHAVIOR AND ECOLOGY OF ANIMALS, WITH DESCRIPTIONS OF EQUIPMENT.[1]

By Victor E. Shelford.

University of Illinois, Urbana, Ill.

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I. INTRODUCTION.

Repeated enquiries as to methods used in college and university instruction in ecology have come to my attention in recent years, and lead me to prepare this paper to describe the equipment which has been developed and the methods of its use, in the laboratory work in recent years at the University of Illinois and the University of Chicago. The purpose of the field and laboratory work described herein is to show the different environmental situations into which the general conditions of a locality may be classified, the intimate relations of animals to these environments, and the close correlation between the conditions in the different environments and the physiological characters of the animals living in them. It also aims to show the relations between animal activities, rate of development, etc., to weather, season, etc. Certain qualification on the part of the teacher and certain natural features in the vicinity of the institution where the work is given are important. Some diversity of undisturbed environment should be present. For the aquatic work a good, swift stream, with alternating pools and rapids, and some stagnant ponds are essential. These are more likely to be preserved than forest or natural meadow. A piece of woods of twenty acres or a smaller area in a sheltered valley, of the original denseness and quite undisturbed, meadows and shrubby forest edges or roadsides are important for work on

[1] Contribution from the Zoological Laboratory of the University of Illinois, No. 84.

land animals. If a wood is much disturbed, or the trees thinned, or particularly if it is pastured, and if grass has taken the place of the usual undergrowth and the carpet of leaves has been destroyed, the original characteristic forest animals will have disappeared so as to make the results in the forest exercises to be described later, questionable. However, in the absence of such woods, the teacher may select animals from habitats that differ obviously in conditions and obtain good comparative results.

Like all other kinds of teaching, the teaching of animal ecology requires a knowledge of materials and results which only training and experience can give to the best advantage. In the experimental and field work the most constant demand on the teacher is for helpful interpretations of field conditions and of the student's results and observations, particularly where experiments are not clear-cut with reference to the factors used. The ability to guide the student at this point, and guide him aright, is perhaps the teacher's best asset. For example, it must be recognized that many animals do not react to light in the ordinary intensity-direction gradient which one gets with simple apparatus, and in other cases in the square pans that must be used for such work animals that do not react sharply to the stimulus in hand often crowd into the sharp corners of the pans, perhaps due to contact response. However, with a good knowledge of his local fauna, the teacher can gain much by daring with experiments and assigning interpretations as far as the experience of the class can determine them.

The teacher is further put to the test in deciding what animals will give results in experiments in the field and laboratory. He must further have a knowledge of the effects of factors which are varied in experiments, e. g., sunshine and temperature are fatal to some forest animals. He must know whether the animals used in the experiments will give responses to the stimulus to be tried. In general, snails, spiders, grasshoppers, and others whose locomotion is special should be avoided in many kinds of experiments. On the whole the experiments here noted are designed to show the relation of the physiological characters to conditions and give as good drill in the control of environmental conditions as is practicable in a short time. The more complicated experiments are designed for the laboratory, but the field experiments are adapted to laboratories which have little equipment and where field work is not practicable.

II. FIELD WORK.

It has been found best not to mix taxonomy and ecology in the same course. The students are merely told what animals are, and perhaps a word as to how to distinguish them, in so far as they are known to the instructor. Those that are not known are merely noted as different species and designated as representatives of a family or a genus, whichever is known, No. 1 or No. 2 if more are encountered. Since different species have different ecological constitutions, much important information may be imparted by mere recognition of the fact that species are different. Before any experiments are performed, the students are required to write notes on the habitat, weather, etc. The habitat is then divided into sub-habitats, strata, etc., and the student is directed to find and note the positions and habits of the animals of each stratum separately. The notes consist of the scientific name, the common name, habitat, (location, activities) arranged in three columns on small sheets of paper with vertical and horizontal rulings. The student is expected to write his notes between certain heavier horizontal lines provided for the purpose. The notes are collected at the end of the excursion and read and corrected.

The students are taken into the field, or are given time in connection with some other excursions, to observe and to record the activities of animals coming to a particular plant or on a particular small area of ground. They record the activities of a number of animals for half an hour or of a single animal.

III. METHODS OF COLLECTING AND KEEPING OF ANIMALS ALIVE.

From the standpoint of experimental work, there is no more important consideration than to get animals into the laboratory and to keep them alive.

1. Treatment of Laboratory Water Supplies.

Water from deep wells usually contains no oxygen and often a large amount of carbon dioxide making it unfit for animals to live in. At present many city water supplies are chlorinated, and those that are not are commonly supersaturated with gases which cause gas bubble disease in animals. To render such water suitable for experiments and for keeping animals alive, aerating devices have been constructed. Figure 1 shows one of these (4 ft. long, 6 ins. wide, 6 ins. deep, and 18 ins. high at A). It con-

sists of an inclined trough, three inches wide, with a crimped bottom in three sections arranged like a broken stair case. Water is run onto the trough at A, and, after flowing the length of the incline, it enters the long tank at B. It must then pass under the partition at C, over the first crimped baffle and under the second at D, over the third and under the fourth, and into the other half of the tank at E. This is separated from the outlet G by the screen F. This arrangement of baffles so aerated the

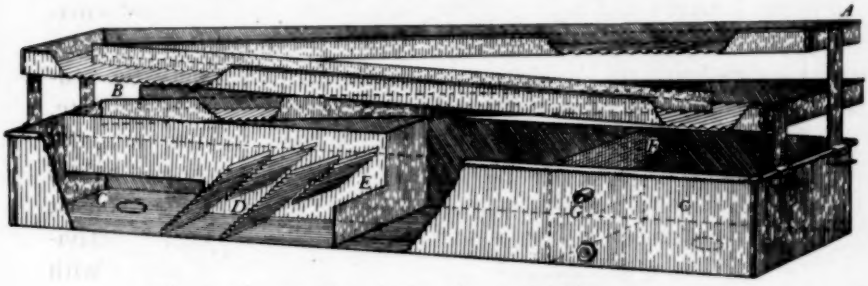


Fig. 1—An aerating device; for description see text.

deep well water at the University of Illinois as to precipitate and remove a large amount of iron held in solution by the carbon dioxide acidity. All kinds of animals live well in this water. Water which contains an excess of nitrogen or sediment or which has been chlorinated, is greatly improved by such treatment. The device will aerate about 1 gallon of water per minute and is used for supplying aquaria and water for experiments.

2. Equipment for Keeping Animals Alive.

Figure 2 shows a student work table to accommodate two students on each side. Two lockers and two drawers hold the student equipment, which will be described later, together with other things used. Each table is supplied with hot water, cold water, electric outlets, and compressed air. Each has also a large water-storage tank with a small aerating incline, supplied with cocks along each side. This represents an earlier method of aerating. It is sufficient to prevent the development of gas bubble disease, but for deep-well water the more complete aerating device is desirable. The water cocks in the tank have the additional advantage of supplying water for experimental work under low pressure, which is very desirable.

For the keeping of stream animals alive between the date of collection and the time for experiments, Figure 3, a long galvanized iron box, 25 x 5½ x 5½ inches (62 x 14 x 14 cm.), with

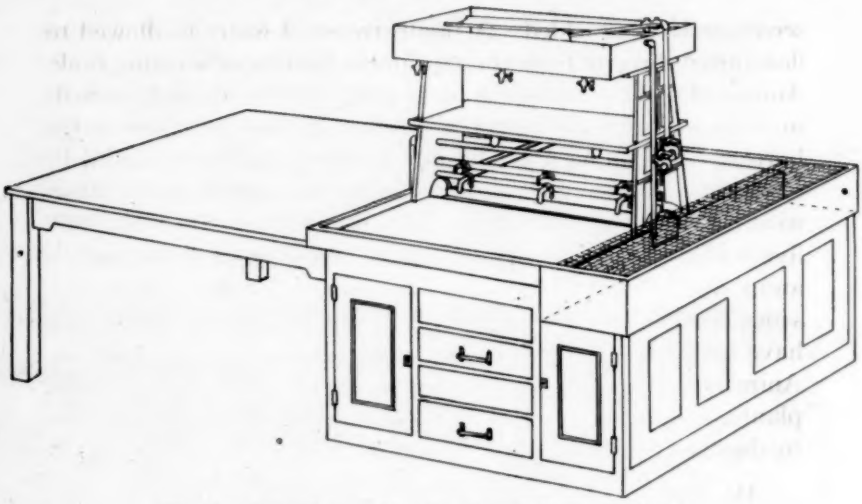


Fig. 2—A student table; for description see text.

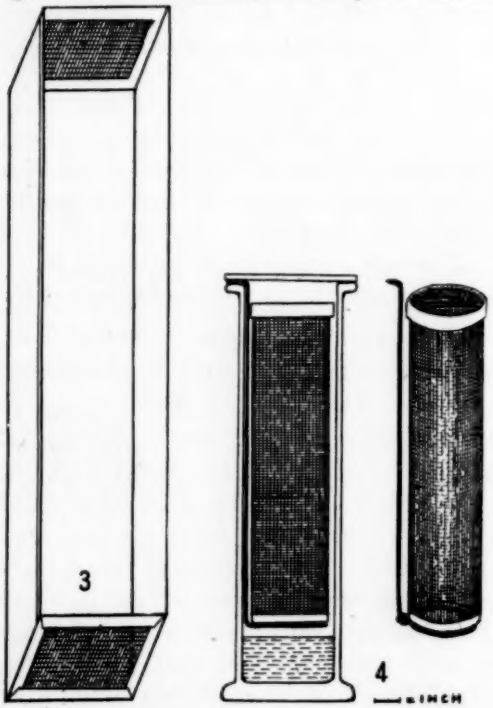


Fig. 3—Screen-ended box, into which aquatic animals are placed and water allowed to run onto them from small cocks above. The water is about one-half inch deep.

Fig. 4—An hydrometer jar with cage and wire to hold it up from the bottom in which there is about two inches of water. Land animals supplied with fresh plants every few days will live in these for months.

screen ends, is provided. A small stream of water is allowed to flow into it directly from the taps in the bottom of aerating tank. Animals live here for weeks or months. To bring such animals in, a large-bottomed bucket with about an inch of water in the bottom is the best for small fishes and nearly all other animals.

Land animals may be swept from the vegetation or otherwise collected, but when brought to the laboratory they will live for only a few hours. A wire cage suspended over water and loosely covered with a glass plate as shown in Figure 4, provides conditions in which they will live for days. Such cages have been used in very large hydrometer jars, battery jars, etc. Animals collected from vegetation are supplied with suitable plants, and those from under logs or from soil are accompanied by decayed wood or soil from their habitats.

IV. FIELD AND LABORATORY EXPERIMENTAL METHODS.

1. Mechanical Stimulation.

a. Shock and Vibrations.

In the field the students are directed to watch animals on plants and note their behavior when the plant is suddenly jarred. A tuning fork may be profitably carried for experiment on the response of orb-weaving spiders. In the laboratory the falling ball experiments of Banta and Allee are repeated. The threshold of stimulation is determined according to Banta and Allee. Isopods, planaria, or cockroaches (*Blatta orientatis*) give good results.

2. Thigmotaxis—Reaction to Bottom.

Field experiments are performed with burrowing and rotten wood inhabiting animals. Striking positive responses are the rule with tiger beetle larvae when the abdomen is thrust into a hole in the soil, and with various insects living under bark when similarly treated.

The laboratory is supplied with mica in small bits, broken glass, crushed stone, sand, pebbles and quartz of various sizes supplied by the Wausau Quartz Co. (Wausau, Wisconsin). Experiments on reactions to bottoms are usually set up in the circular rheotaxis pans (Fig. 5), the space between the large and the small pans being filled with various kinds of soil or different sized quartz. Animals are placed in this space (covered with water for aquatic animals) and readings of the positions of the animals taken once in several days. Good results in selection of bottom

materials are usually obtained with animals which live in the bottom of streams or in or on soil. For thigmotaxis with other animals, one-half of each of the cake pans (Fig. 8) described on the succeeding pages is covered on the bottom with leaves, mica, or the like. The pan is covered with the light, tight cover and the cover removed at intervals for readings.

3. Geotaxis.

In the field the students are directed to observe the orientation of animals such as the grasshopper, which usually orients

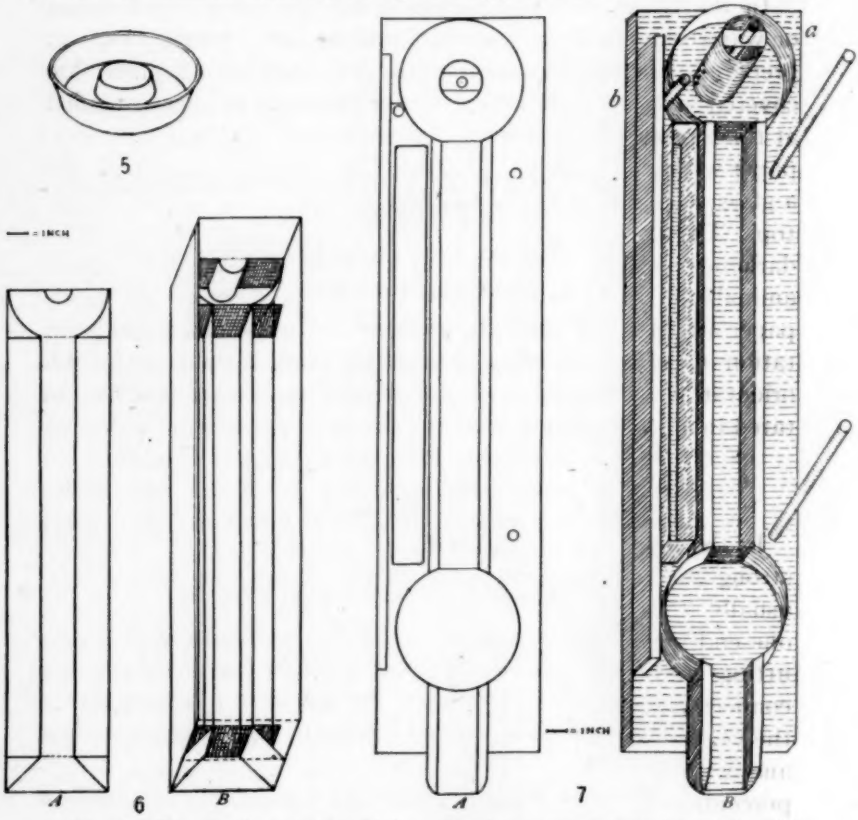


Fig. 5—Rheotaxis pan in which a circular current may be made with the hand. Also used for experiments with different kinds of bottom or soil (see page ——).

Fig. 6—A rheotaxis box. A shows ground plan; B is an isometric drawing. The box is set in the brook and water flows in between the two semicircles, through the screens in the lower half of the upper end; the two currents meet where they start down the central trough and zigzagging is prevented. The side troughs are used for controls.

Fig. 7—Allee's straight-current box. A plan of box with control box added by the author and cooling space along side. The posts are for supporting electric lights.

Fig. 8—7 B is an isometric drawing of the same.

with the head up, and katydids, which usually orient with the head down. Aphids, many of which orient with the head down, are inverted by cutting the plant off and fastening it bottom side up. In a half hour to an hour the position of the aphids is noted and the position of a considerable number has usually been reversed. Some Chrysomelids always hang to leaves, etc., with their backs down. Usually students may be directed to note consistent orientation or lack of the same in animals and record them.

In the laboratory, experiments may be performed with land or water animals in tall battery or other jars. Usually four are prepared. One is completely covered with black paper and covered with a tin cover so as to exclude all light; one is covered at the top with a tin cover and the sides are enclosed with black paper within three inches of the bottom; another is covered with a glass plate and with black paper to within three inches of the top. The fourth is left entirely light. The four are placed in a darkened portion of the room, and filled with water if aquatic animals are to be used. For land animals strips of corrugated paper are placed upright in the jars and the positions and orientation of the animals noted by reading at regular intervals. The orientation of snails can be tested on a glass plate which is rotated in an oblique position.

4. Reactions to Currents.

a. Anemotaxis.

In the field, orientation of flies in the wind when it is not too strong can usually be noted. In the laboratory a large tube, usually a straight lamp chimney, is provided. It is closed at one end with a screen, and a hose which passes through a loose fitting stopper is introduced into the other end. The hose is connected with the compressed air supply. Insects living on the vegetation are introduced into the tube, usually one at a time, and with suitable adjustment of the air usually show a high percentage of positive orientation. An electric fan may be substituted for compressed air.

b. Rheotaxis.

(1) *Field Study With Rheotaxis Pans.*—Field study of rheotaxis for comparative purposes may be conducted with the double pans, Figure 5, which consist of two pans, one 5″ and one 12″ in diameter, soldered together. Similar animals with similar methods of locomotion, such as swimming animals or creeping

animals, may be used for field exercise as follows: Animals are collected from the rapids of a stream and from a near-by pond. A current is made with the finger by passing it around the pan until a strong current is produced.

The following animals were secured from a brook:

1. Argia, brook damsel fly nymph, from under stones in rapids.
2. Hydropsyche, caddis worm from rapids.
3. May fly, from under stones in rapids.

The following animals were secured from a pond:

4. Haliplid beetle.
5. Corixids.
6. Small sunfish ¾ inch long.

The current was started with the finger, and when well started the hand removed and the order of orientation noted. At first the animals are swept around.

First reading. The animals oriented with heads toward the current in the following order: (1) Caddis fly larva, (2) Damsel fly nymph, (3) May fly, (4) Haliplid beetle, (5) Corixid, (6) Fish.

Second reading. The same, except the fish preceded the Corixid, 1, 2, 3, 4, 6, 5. (Numbers refer to list above.)

Third reading. Like second, except May fly last, 1, 2, 4, 5, 6, 3.

Fourth reading. Like second, 1, 2, 3, 4, 6, 5.

Fifth reading. Like second except Haliplid before damsel fly, 1, 4, 2, 3, 6, 5.

Thus on the whole the animals orient to the strength of current corresponding to that in which they live with occasional irregularities.

(2) *Field Rheotaxis Boxes* (Fig. 6).—These are modeled after Allee's box. The large box is 25 inches (63 cm.) x 5½ inches (14 cm.) x 5½ inches (14 cm.). One-half of each end of the box is removed and replaced by screen. The end which is placed upstream is supplied with two semicircular partitions, the larger with a radius of 2¾ inches (7 cm.); the smaller with a radius ⅓ inch (1¼ cm.) as shown in Fig. 6 a and b. These partitions are 2 inches high and connected with two others which run to the end of the tank, 4 cm. apart. At the distance of 50 cm. from the semicircle the partitions bend to the corners of the box. Thus, with a screen to separate the long central part of the box from the end chambers, a box in which the animals may be confined and through which the water of the stream may flow, which is 4 x 50 cm. (which is the size of Allee's current trough), is provided. The partitions which make the sides of the central trough through which the water flows, make two side chambers, which, with the addition of screens, make chambers like the cen-

tral trough and which may be filled with water and serve as control chamber.

These boxes are carried to a stream, and, after the students are familiar with the fauna and the habits of different species, the boxes are fixed in the stream, and the rate of flow through them is determined by dropping in bits of paper. Animals are assigned to each student by the instrutor. They first place the animals in the experimental trough and take note of their behavior. The tendency to cling to the screen is noted, their speed of movement against the current, etc. The boxes are adjusted in the stream so as to give an amount of water and rate of flow suited to the animals at hand. The student is then directed by suitable questions to note that the animals on the screen are not in a position to orient to the current and are usually clinging and inactive. They are then directed to make two (or one) categories for the animals that are not reacting to the current; and three for the animals that are in the current,—positive (+), indefinite (∞), and negative (—). The last three are for the animals that are actively swimming in the water or in the current on the bottom.

Readings are taken at regular intervals of 1 or 3 minutes as a rule. One student reads the experiment with watch in hand while the other records, usually during the first five readings, when the men change places for the next five. The students are given an opportunity to calculate their results for a general conference. The characteristics of the rapids community—namely, its strong tendency to cling to objects or rest on objects (e. g., darters), and its very high percentage positive orientation in strong current—are demonstrated. If a class is large enough a considerable amount of comparative work may be done. Some students may be assigned to the animals of pools between rapids in the stream as is shown in the case of fishes like Notropis and the darters. Both are strongly positive, but the darters rest on the bottom. With a strong current relative efficiency may be tested and the darter found most effective.

On these excursions the instructor carries one of the long screen ended boxes used for keeping animals alive and another box which just goes inside of it but of nearly the same dimensions and with a glass bottom. A minnow is placed in the glass bottomed box with about one inch of water. This is held securely in the hands and carefully moved from left to right about two inches above a gravel covered shore. The fish turns about when the

Table 1.

Showing the reactions of four species of stream animals to current in the field rheotaxis boxes when set in the rapids of the stream from which the animals were taken. The habitats of the animals are as follows: Hydropsyche, in rapids under and on stones; Corydalis, under stones in rapids; darters, among stones in rapids; minnows, in pools.

SPECIES.	EXPERIMENT.									CONTROL.								
	Per cent resting on bottom.	Per cent on upper screen.	Per cent negative.	Per cent indefinite.	Per cent positive.	Per cent on lower screen.	Per cent of active indefinite.	Per cent of active positive.	Per cent of active negative.	Per cent resting on bottom.	Corresponding to per cent on upper screen.	Corresponding to per cent negative.	Corresponding to per cent indefinite.	Corresponding to per cent positive.	Corresponding to per cent on lower screen.	Corresponding to per cent of active positive.	Corresponding to per cent of active indefinite.	Corresponding to per cent of active negative.
10 Corydalis[2]	4	0	0	22	74	0	100	0	0	27	10	0	11	52	47	0	53	
10 Hydropsyche	0	1	0	39	60	0	97	3	0	3	9	0	9	79	50	0	50	
3 Etheostoma coerulum	100	0	0	0	100	0	0	100	0	0	0	33	27	40	0	40	27	33
10 Notropis sp.	0	0	0	0	100	0	0	100	0	0								

[2] Current 11 cm. per second.

gravel appears to move from tail to head. There is some disturbance of the water however, but the experiment is highly suggestive of the slight orientation described by Lyon. The large screen ended box is used to demonstrate the orientation of some of the larger fishes in the current.

(3) *Laboratory Study of Rheotaxis.* The laboratory rheotaxis box designed by Allee is shown in figures 7a and 7b. It is made of cypress, except the circular boxes, which are metal. The experimental trough is 4 x 50 cm. and is supplied with water from a circular well. Water runs into this well from a smaller, deeper well with holes in the side away from the experimental trough through the hose end (h). The outlet to the lower well is raised 1½ cm. The apparatus gives a straight current. Several features have been added to Allee's device. The box 4 x 50 cm., which is made of sheet metal, rests between the main trough and a wooden outside wall. The wooden outer wall is ½ inch from the wells. The space between it and the well at the upper end is blocked by a piece of brass tubing with a hole in one side of the lower end which serves to run water around the metal control box and keep it at the temperature of the experiment. Posts to hold symmetrically placed lights have been provided for some of the rheotaxis boxes. These boxes are used for experiments of greater precision than the field boxes. In these the flow from the

lower end of the trough is measured in cubic centimeters per minute. The depth at the centre multiplied by the width gives the area of the cross section of the water in sq. cm., thus, $\frac{\text{volume per minute or second}}{\text{square cm. in cross sec.}}$ = velocity, in cm. per minute or second. The rate of flow can be controlled by changing the flow of water and raising or lowering the upper end of the trough. The character of the current can be determined by adding sand or carmine. These experiments are performed under symmetrically placed lights in a darkened room or under a hood. Experiments showing current in which a given species gives greatest per cent of positive orientation can be worked out with precision and different species compared. Also differences in metabolism, etc., can be illustrated by differences in rheotaxis (Allee).

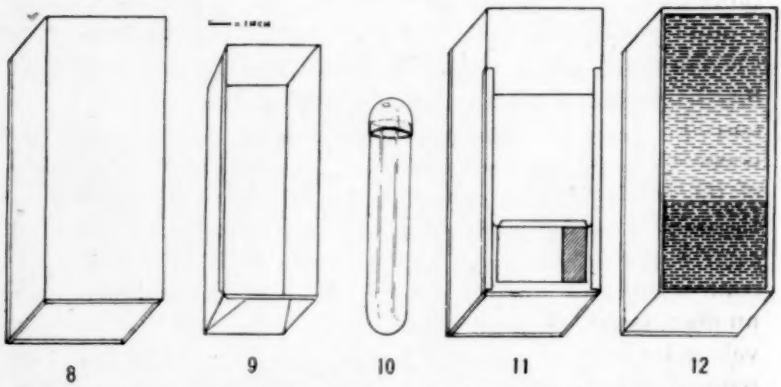
Other methods of studying rheotaxis have been tried. Lyon's belt apparatus has been used. This consists of a frame bearing a roller at each end, over which an endless canvas, with dark stripes painted across, passed under a long glass bottomed box. Fresh water fishes did not respond well to this.

Another piece of apparatus modeled after the turn table described by Lyon has been used with better success. It consists of a large, round, glass aquarium jar 14 inches in diameter, in the centre of which is placed a 5 x 8 inch battery jar, weighted so it will not float in water and the inner walls lined with black paper. Water to a depth of 1–3 inches is placed in the large jar and the fishes to be tested placed in this. They are thus confined in a circular space about 4 inches wide. A galvanized iron bushel measure with a ⅜ inch close nipple lock nutted in the bottom has been set over the rod of a large iron support with triangular base. The rod has been cut off, so that the top projects above the ⅜ inch threaded pipe, and an iron pipe flange with a suitable wooden platform of the size of the bottom of the smaller jar has been screwed into position. The jars with the fishes in position are placed on the platform. The bushel measure has been painted to simulate the colors of a brook bottom and sides with contrast exaggerated. When the bushel measure is turned the jar stands still and the orientation of such fishes as orient by sight can be demonstrated; cyprinids usually orient well when first put in.

5. Reactions to Light.

a. Field Experiments.

The equipment for field experiments on light is not of such a character as to meet the approval of the student of the analysis of behavior with reference to light from the modern physiological point of view. The purpose of the experiments performed differs materially from those of the persons who would determine whether the animals react to direction or intensity, or who seek to determine the effect of light upon the organisms. In most of these experiments the purpose is to determine the reactions of the animals to light, differing both in intensity and direction and with the heat rays not screened out—in other words, light as it affects animals in their natural environments. Experiments with colored glasses are performed with a view to show the usual correlation between reaction to intensity and color.



Figs. 8–11—An isometric drawing of galvanized iron covers, glass holder, with cake pan and tube for enclosing animals for light experiments. 8 is the light, tight cover; 9, the cake pan; 10, a tube for enclosing animals; 11, cover with slit; 12, holder for colored glasses.

The equipment consists of sponge cake pans, 10 x 30 centimeters at the bottom and slightly larger at the top and 7 cm. deep (Figure 9), painted with flat black paint. Tubes[3] about 4½ cm. in diameter (Figure 10), with hemispherical ends and caps of the same shape slipping on so as to make the tube in place about 30 cm. long, are provided. These are painted flat black on ⅓ of the inside circumference, which is placed downward in the experiments. Each student is provided with two pans, preferably two tubes and a thermometer. Covers for the pans are three in number; one is a simple tin box, deep enough to rest on the ground when over the pan (Fig. 8); the other, a cover with an adjustable slit (Fig. 11), and the third a holder

(Fig. 12) for a red, green and blue glass. The covers fit neatly one inside the other, the holder for glasses being smallest. The entire outfit may be packed inside the two covers, together with a thermometer, making a package of the size of the largest cover which is conveniently carried in a shawl strap.

One excursion for experiments with light is conducted to a piece of primeval forest large enough to have a fauna characteristic of such woods. Here animals are observed and collected from the various levels or strata. In the experiments, usually for comparative results different animals are assigned to different students. One pair of students is given animals from under logs and bark and animals from the herbaceous vegetation; another, from the surface of the ground and from the shrubs or from the herbs and from the shrubs. A number of individuals of a particular species are usually brought together in one of the tubes by a student, and then divided between two tubes, while a number of individuals from another stratum is prepared in the same way by the student's partner and mixed with these (or, if the angle of the sun is such that the two tubes can be exposed to the same light, they are both kept separated). A slit is opened in the slitted cover so as to give an exposure of a part of the bottom of the tube to direct sunlight. The balance of the tube is divided into halves. The control is set up in the same way and completely covered, except during readings. The control tubes are divided into three corresponding parts. The number of individuals in each part is recorded at definite intervals of 1-5 minutes and totaled at the end of the observation and reduced to per cent.

On these excursions the instructor carries a Wynne exposure meter in common use for photographic work and compares the light intensity in the habitats of different animals in so far as is practicable.

The results of the experimental readings of a class in the field at Warner's Beech Woods, Three Oaks, Michigan, August, 1914, are given below. The control readings which were symmetrical, in most cases are not presented.

Reaction to colored light nearly always shows the animals with greatest percentage in the dark with greatest percentage under red glass.

The experiments show that there is a physiological difference between the animals of the different strata. The animals show a uniform increase in positive response to light as we pass from the lower to the higher strata.

Table II.

Students comparison of Phototaxis of animals from different strata in Beech Woods. Experiments done in woods. L, light third; M, middle third; D, dark third. Figures, per cents of total individuals read. Five individuals, ten readings, every two minutes.

Habitat.	Animal.	L.	M.	D.
1. Under loose bark; subterranean stratum	Centipeds	0	18	82
	Beetle larvae	4	0	96
2. Ground stratum	Frogs	16	52	32
3. Herbs, field stratum (6 in. from ground)	Spiders	42	13	45
4. Shrub stratum (6 ft. from ground)	Leaf hoppers	70	30	0

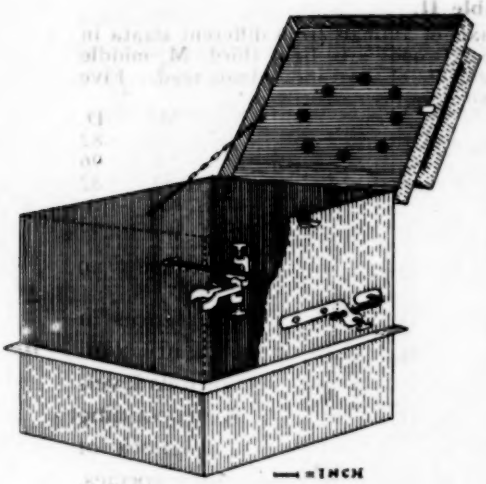
A second type of study designed to show the differences in the physiological make-up of animals from different communities is shown in Table III. Animals from the various levels of the forest are mixed with animals from the corresponding levels of the road and roadside. The species characteristic of the roadsides are commonly what is termed forest edge species. When such comparisons are made and the number of pairs of students permits, the experiments are performed simultaneously in the woods and in the road.

Table III.

Comparison of Phototaxis of animals of the same strata in woods and open roadside. L, light third; M, middle third; D, dark third. The figures are per cent of total individuals read. Five individuals, ten readings every two or five minutes.

	Habitat, Stratum, and Conditions.		Per cent in thirds. L.	M.	D.
1	Expt. strong light (road).				
	Ground; taken from woods.	Frog	10	36	54
	Ground; taken from road.	Grasshopper	70	12	18
2a	Expt. in strong light (road).				
	Herbs; from woods.	Flies	6	40	54
	Herbs; from road.	Treehoppers	50	25	25
2b	Expt. in faint light (forest).				
	Herbs; from woods.	Small Leafhoppers	46	22	32
	Herbs; from road.	Large Leafhoppers	28	34	28
3a	Expt. in strong light (road).				
	Shrubs; from woods.	Mixed insects	54	18	28
	Shrubs; from road.	Mixed insects	78	2	20
3b	Expt. in faint light.				
	Shrubs; from woods.	Mixed insects	49	16	35
	Shrubs; from road.	Mixed insects	58	42	0

A comparison of 1, 2a, and 3a, all performed in strong light, shows that the animals from the same strata in the roadside and forest differ strikingly in reactions. Grasshoppers from the road are positive and frogs from the woods are negative, etc. There is, accordingly, a marked difference in the physiological character of the animals from the same level in different habitats or communities. In the faint light of the forest these differences do not appear striking.



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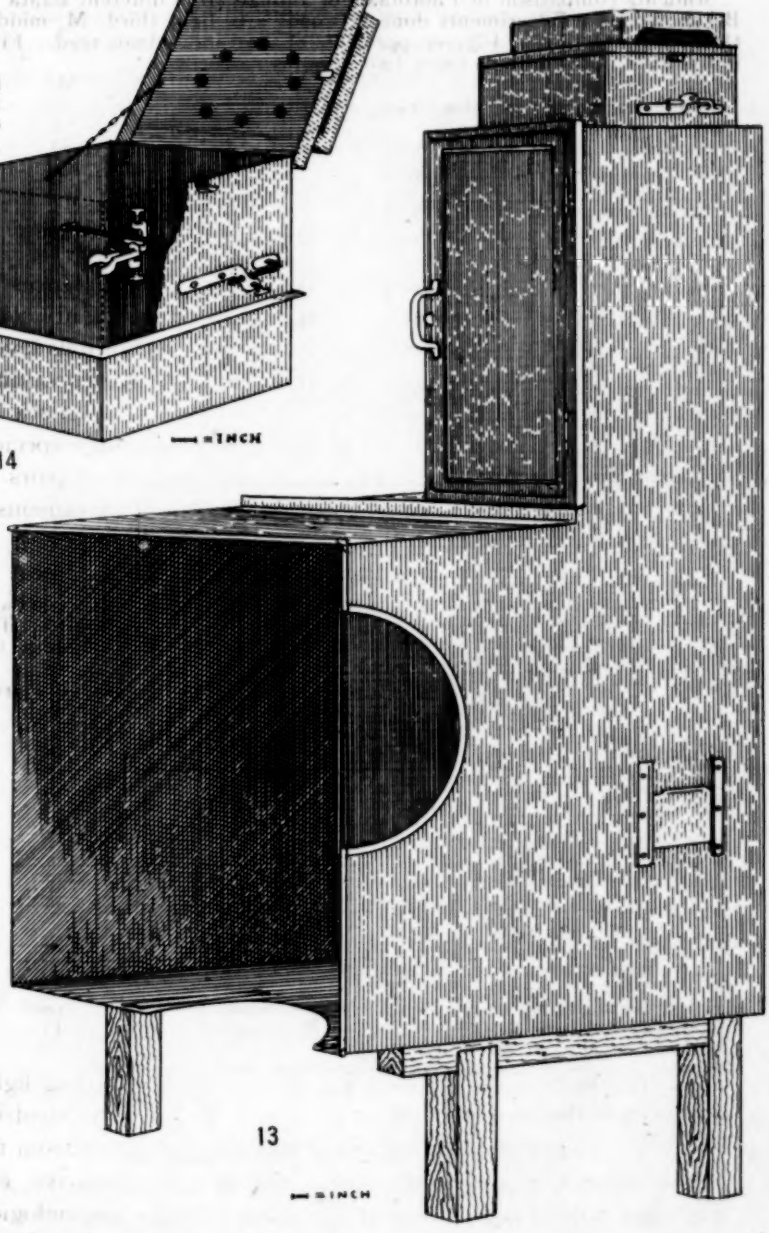

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Fig. 13—A hood-form, light grader box; a dark curtain covers the front.

Fig. 14—The Freyer adjustable top for holding Nernst lamp.

After such an exercise the students are given an opportunity to calculate their results and the whole subject of stratification of forest animals is discussed, on the basis of the differences noted in this connection and in connection with temperature experiments to be described later.

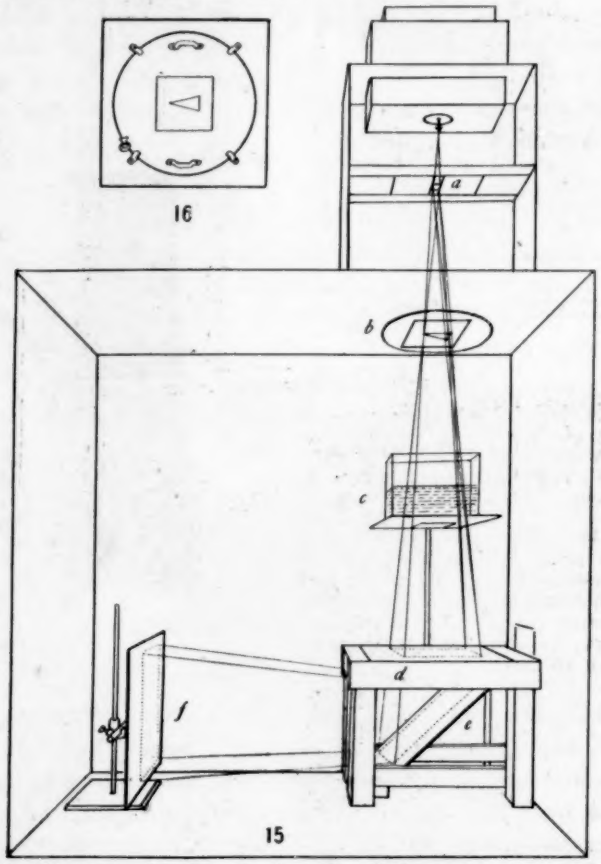

Fig. 15—Diagram showing the interior of the grader box. The light from the lamp first passes through the adjustable opening at a; then through the lens, b; the water screen, c; the glass platform, d; is reflected by the mirrors, e and f, against the black curtain.

Fig. 16—The turn-stage of the lens holder which is used when the apparatus is turned on its side.

b. Laboratory Study of Light Reactions.

This work is done with a great variety of animals, as there are few that fail to react. For the simplest experiment the lights on the table are used with the shades drawn and the reaction to 40 watt Mazda lamps is noted. Hoods 80 x 20 x 40 cm. with a hinged conical top with a convenient slit for observation are

used, with two extension lights with switches in the cord so that either can be turned off or on without disturbing the equipment. The animals are placed in a long box of some kind and the light turned on and off at the ends and their reactions to directions noted. Good results can be obtained with earth worms.

Yerkes light graders as described by Mast are provided in a dark room at the University of Illinois, but where dark rooms are not available, a dark box with a tower for the lamp has been used for some experiments. The most important modification of the Yerkes-Mast apparatus is the 45 degree box for holding

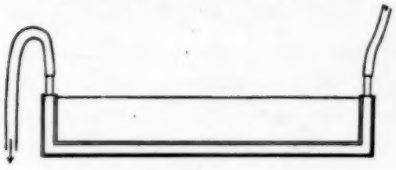

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Fig. 17—A longitudinal section of the light grader experimental box, showing hollow ends and bottom through which cold water or cold air may be passed to keep the temperature down.

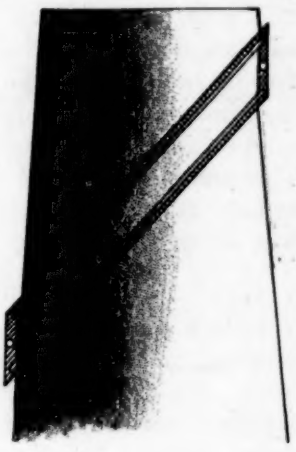

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Fig. 18—The experimental box in ground plan, with graded beam of light passing through the glass sides. With this animals which are negative to direction will work their way into the dark, as well as those which are negative to intensity.

animals. This was suggested in connection with experiments by the author (1914) in which it was found that, while some stream animals react to direction of light and others to intensity, animals from the same community and strata react in a similar manner and all go into the dark, for example, when the direction carries them in same way as the decreasing intensity.

No attempt to work with monochromatic light has been made except with colored screens, but others have described apparatus for the same.

6. Reactions to Temperature.

In the field, temperature experiments are often performed in the cake pans or tubes described in connection with light. Usually the animals are placed in tubes which are laid in soil that has been in the sun and soil that has been shaded during a summer day, so placed as to allow one-half of the tube to rest on one and

the other half on the other. Temperatures are taken at the surface of the soil, and the results are similar to those obtained with light. Animals from different temperature strata react differently to temperatures just as they do to light intensities.

In the laboratories temperature gradients are established and maintained by placing 2 cake pans on the water table and allowing hot water to flow into one and cold into the other. A third cake pan is set across these two so as to allow the water to come in contact with the cold at one end and the warm at the other. If the temperature at the warm end becomes too high the contact with the hot water is decreased. Standing water heated with an alcohol lamp has been successfully substituted for the flowing hot water. About a half inch of water is used in the experimental pan for aquatic animals, and a thin layer of fine sand or fine quartz is used to cover the bottom for land forms. Thermometers are used to take the temperature. Students are usually asked to graph the movements of the animals lengthwise of the cage.

7. Graphic of Animal Reaction.

At this point the students are introduced to the methods of graphing animal reactions. For this the experiment blanks are used. The distance between the two outer red lines is taken to represent the length of the gradient, the middle red line is the centre, and the blue lines divide the area into sixths. The use of the entire space is desirable with beginners, as much more skill is required to graph accurately in a short space. The spaces between the lines as numbered vertically on the paper are used to represent minutes. Figure 19 shows a typical graph. This graph shows a sharp avoidance of the air of high evaporating power on the part of the red-backed salamander. This gives a full detail of the movements of the two animals for 20 minutes, of which the first 10 are shown here. Taking reading for the entire 20 minutes:

Every half minute gives	81	8	11 per cent in the thirds
Every minute gives	82	10	8 per cent in the thirds
Every two minutes gives	90	5	5 per cent in the thirds
Every half minute for 10 mins. gives	75	10	15 per cent in the thirds

This antecedent exercise in many cases shows wider divergence with the different methods of reading, and serves to show the student the need of precision in taking down results.

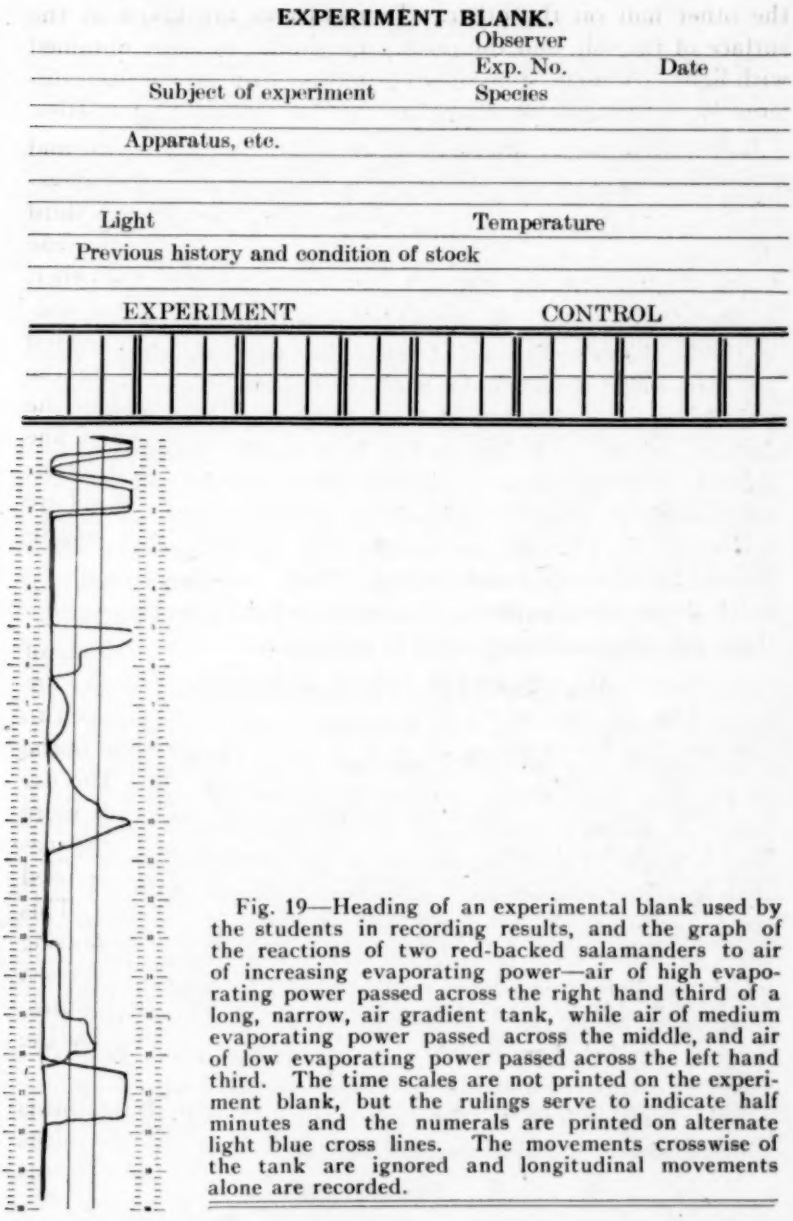

Fig. 19—Heading of an experimental blank used by the students in recording results, and the graph of the reactions of two red-backed salamanders to air of increasing evaporating power—air of high evaporating power passed across the right hand third of a long, narrow, air gradient tank, while air of medium evaporating power passed across the middle, and air of low evaporating power passed across the left hand third. The time scales are not printed on the experiment blank, but the rulings serve to indicate half minutes and the numerals are printed on alternate light blue cross lines. The movements crosswise of the tank are ignored and longitudinal movements alone are recorded.

The more advanced students do an experiment with air of different evaporating power, temperature, with CO_2 added, etc., and the results of the animals graphed, the temperature, wet and dry bulb readings, evaporation, etc., and velocity of air being recorded. Similar experiments are performed with water gradient tanks described by Allee, the writer, and Wells.

V. MODIFICATION OF BEHAVIOR.

Modification of behavior in ecological courses is usually effected by starvation, differences in light and temperature or oxygen and carbon dioxide content in water.

The experiments with light and temperature are performed upon various kinds of animals, an ice box and warm chamber being provided in the laboratory. Planaria are often used for the same experiments. The reaction of the stock to light in a Yerkes grader with the oblique box is noted and the stock is then divided into two lots, one of which is fed daily for a month or less while the other is starved under the same conditions. Some are kept well fed and under a 40-watt electric light; others, in a dark room or chamber and fed well. Some are kept at 33 degrees; others, at 8 degrees C. It is highly desirable to feed animals to be used for tests in differences in light and temperature reactions. Starved animals are usually sluggish. The reactions of the planaria are usually but not always reversed to current by starvation and feeding. Their reactions to light are much slower when starved. Exposure to light sometimes makes them negative and more rapid in movement.

VI. QUANTITATIVE STUDIES.

A. Aquatic.

An aquatic tow net of bolting cloth on an oblong ring 20 x 25 cm. is drawn a definite number of meters through a body of water at different speeds and at different depths. One slow haul is made by drawing the net at the surface of the water so that it is just submerged. After this, a dipper, with the same sized opening as the net and holding 4 liters, is used to dip 100 liters of water from the surface down to a depth equal to its width, so dipped as to get water as near as possible from the same layer as the net. These collections are diluted to a hundred cc., well shaken, and five cc. poured out into a petri dish ruled into squares and all the Entomostraca counted and the relative number from the different methods of collecting and the different levels and localities determined.

B. Terrestrial.

Heavy metal cans are provided 12 inches high and 16 inches in diameter. They are provided with strong handles and a screw cap at the top. The edge of the can is shoved into the soil. A heavy knife, with which the sod is broken, assists the process. Chloroform is poured in and left until the animals have died.

Meanwhile, the grass and sod for some distance around the can has been removed and when the latter is lifted the area on which the animals have been killed is clearly marked off. The animals are then counted and the number per acre determined, also the number per hectare. The students are then asked to count the number of butterflies seen on a definite area and the number of grasshoppers scared up in walking.

VII. MODIFICATION OF LIFE HISTORIES.

In the autumn various experiments with insect larvae can be performed. The reactions of larvae to temperature may be tested before and after being subjected to freezing conditions. The reactions to temperature will be modified. If the freezing is done suddenly the animals will die, while if they are left out of doors all the time to the date of freezing they will survive. Some hibernating larvae may be induced to complete their transformations by freezing.

Soil gathered from the bottom of a pond where Branchipus is known to have bred, usually produces Branchipus after the first hard freeze of the autumn, but not before freezing takes place.

Acknowledgments and Bibliography.

The equipment herein described has been materially improved by the suggestions of the students who have used it and by the men who have assisted in the work. Dr. W. C. Allee and Dr. M. M. Wells have made particularly important suggestions.

The sheet metal equipment described herein is made by R. G. Freyer, 1107 E. 55th St., Chicago, Ill. The special glass tubes with caps are made by E. H. Sargent & Co., Chicago, Ill. The sponge cake pans used are the Royal Enamel & Stamping Company's No. 200, granite or No. 145 sponge cake pan, tin, Catalogue No. 17, which is in the hands of all dealers.

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TRANSLATION, REVOLUTION, ROTATION.

By F. C. Van Dyck,
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Translation.

In Guthe's *Definitions in Physics*, translation is defined as "a motion in which the displacements of all points of the body are linear, parallel, and equal." The equivalent of this definition is usually accepted, as in the concise phrasing of the *New Standard Dictionary*—"motion without rotation."

This type of motion is spoken of in Thomson and Tait's *Natural Philosophy* as *simple* translation; and the term *pure* translation is used by Crew for instance. Those who qualify the word translation by an adjective, "simple" or "pure," do not give a definition of translation *unqualified*.

It is sometimes said that translation is displacement of a body regarded *as a whole*. Let there be a wagon, with only one of its wheels prevented from turning, pulled along on a level road. Does a free wheel move in translation? Not in *pure* translation of course.

Suppose the usual assumption that a body may be regarded as collected at its center of mass to be applicable to this case. Then let translation be defined thus—*displacement of the center of mass of a body*. Also let *pure* translation be "motion without rotation." Then it may be said that, with reference to the earth, the free wheels move in translation, but the blocked wheel and all the rest of the wagon move in *pure* translation.

In the proposed definition of translation, the purpose is to consider only the fact that a body has a *path*, disregarding any *control* of the path; and also to avoid any form of statement which may seem to exclude some other variety of motion simultaneous with translation.

Revolution.

This is defined in the *New Standard Dictionary* thus—"a motion in a closed curve around a center, or a complete circuit or apparent circuit made by a body in such a course; by careful scientific writers used generally in this sense in distinction from rotation." The phrase "apparent circuit" may be taken to include the path of a pendulum bob, or the orbit of a comet which is believed not to be periodic.

In any case, revolution is *translation*, hence it is worth while to attempt an inclusive definition founded upon that word.

Let it be phrased thus: *Revolution is translation in a curved path controlled from an exterior point.*

For example, the earth has an orbit controlled (by gravitation) from an exterior point (sun's center). Also, the path of a pendulum bob is controlled by rigid material connecting it with an axis. Still further, a nonperiodic comet may be said to revolve at least while it is in perihelion.

If an equatorial diameter of the earth pointed at the same star during the year, the earth could be said to have a motion of *pure* revolution; that is, revolution without rotation.

Rotation.

This is defined by Guthe as "a motion in which the displacements of all points of the body are angular and equal."

This fits the case of a *rigid* body, but if water in a vessel is set into rotation by a paddle the angular motions of the "drops" are seldom equal. But vortical motion comes under the general term rotation. If we regard any body, solid or fluid, as made up of parts, rotation may be said to be *revolution of the parts of a body about an interior axis.* If the axis is fixed and passes through the center of mass of the body, the rotation is *pure.* If the fixed axis does not pass through the center of mass, then the body taken in its entirety revolves; but regarded as composed of parts, it rotates.

An excentric, such as is used for operating the steam parts of an engine, illustrates the combination of revolution with rotation. The usual view of an instance like that of the excentric is, as expressed in Crew's *Mechanics:* "When *any* point in a body, or rigidly connected with a body, remains fixed while the body moves, the motion is said to be one of *pure rotation.*" The word "any" is italicized by myself, not in the book.

Thomson and Tait's *Natural Philosophy* is not minutely indexed, therefore, for the convenience of the reader, I refer to pages 60 to 65, Volume I.

The tentative definitions proposed are:

Translation: Displacement of the center of mass of a body.
Pure Translation: "When a body moves so that all lines in it remain constantly parallel to their original positions." [1]
Revolution: Translation in a curved path controlled from an exterior point.
Pure Revolution: Revolution without rotation.
Rotation: Revolution of the parts of a body about an interior axis.
Pure Rotation: When the axis of rotation passes through the center of mass of the body.

[1] Everett in his edition of Deschanel's *Natural Philosophy.*

ELECTROPLATING.

By T. S. Huxham,
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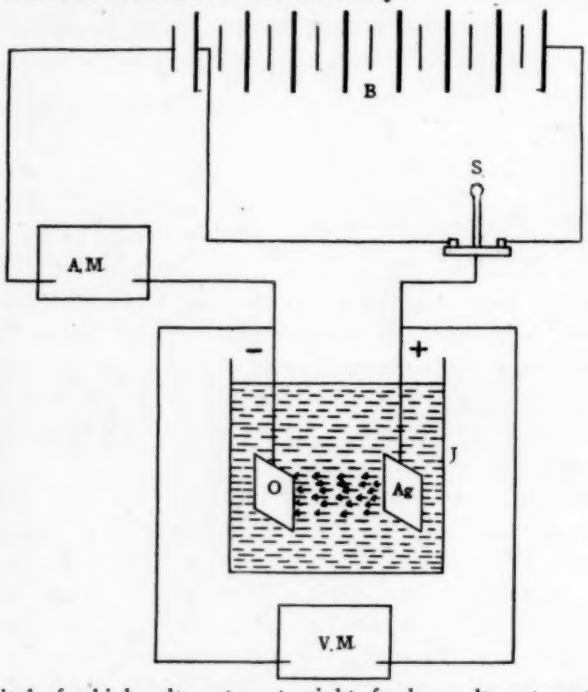
Electroplating is the deposition of one mental upon another metal by electricity. It may be successfully accomplished by anyone who will take the time and pains necessary to do good work. The principal thing to keep in mind is that good results can be secured only by absolute cleanliness. Furthermore, the instructions must be followed exactly.



S.—Switch: for high voltage turn to right, for low voltage turn to lef

Silver Plating.

As silver is the easiest of the metals to deposit, we shall consider that first. The only apparatus needed are a pure silver anode, not larger than a "quarter," a simple form of an ammeter, and a voltmeter. The necessary chemicals may be obtained from the average drug store.

Let us begin with the solutions. Our first consideration is to be sure that the work has been properly polished, and as that is certain to leave a film of grease upon the surface it is necessary to use a solution that will dissolve grease. The first dip is made thus:

SODA DIP:

Caustic soda	226 gm.
Water	2260 cc.

All solutions are made up with distilled water.

If the work is placed in this dip at a temperature of forty or fifty degrees Centigrade, all the grease will be removed. Rinse the work in water to remove the alkali. Oxides and certain salts which remain on the surface are removed by the following dip:

CYANIDE DIP:

Potassium cyanide	57 gm.
Water	2260 cc.

Work placed in this dip needs only to be rinsed and it is ready for plating.

However clean the surface may be, silver may find it very difficult to get a fast grip. We therefore make use of the chemical attraction of mercury for silver, copper, and gold to roughen the surface of the work. The third dip is made by dissolving mercury in dilute nitric acid.

BRIGHT DIP:

Mercury	1 gm.
Water	2260 cc.

Dissolve mercury in DILUTE nitric acid.

Place the work in this dip for a few seconds only, and rinse.

WATER DIP: For rinsing.

Water	2000 cc.

To plate silver upon another metal by an electric current, the work must be placed in a solution of some salt of silver. It is customary to start with silver nitrate as that salt is easily obtained.

PLATING SOLUTION:

1.	Silver nitrate	57 gm.
	Dissolve in water.	
2.	Common table salt	100 gm.
	Dissolve in water.	
3.	Mix 1 and 2.	
4.	Filter off liquid through clean unbleached muslin.	
5.	Wash residue on cloth by pouring water through.	
6.	Potassium cyanide	226 gm.
	Dissolve in water	1700 cc.
7.	Dissolve residue (4) in 6.	

Use 7 as plating solution.

PROCESS.

1. Water dip to wet surface of work.
2. Soda dip, half minute, to remove grease.
3. Water dip to remove soda.
4. Cyanide dip, half minute, to remove oxides.
5. Water dip to remove cyanide.
6. Bright dip to roughen surface (twenty seconds).
7. Water dip to remove bright dip.
8. Plating solution, HOT (40 C).
9. Positive wire to anode; negative to work. (Bubbles should rise from work when current is on.)

10. Eight volts, two amperes for thirty seconds.
11. Remove and rub gently with FINE sand to test whether silver is adhering uniformly. If not, repeat 1-10, omitting 6.
12. Repeat 1-9, omitting 6 to clean work.
13. Use small anode—not larger than "quarter"—trial proves best.
14. Plating solution.
15. One volt, three-tenths ampere—if larger than spoon increase amperage by one- or two-tenths.
16. Burnish.
17. Buff.

NOTE: Great care must be exercised in handling cyanides. The fumes from these are poisonous when inhaled. Fatal results would follow if the chemical entered the mouth or nostrils. It produces painful sores whenever it enters a cut.

THE VOLTA EFFECT PRODUCED WITH A METAL AND AN ELECTROLYTE.

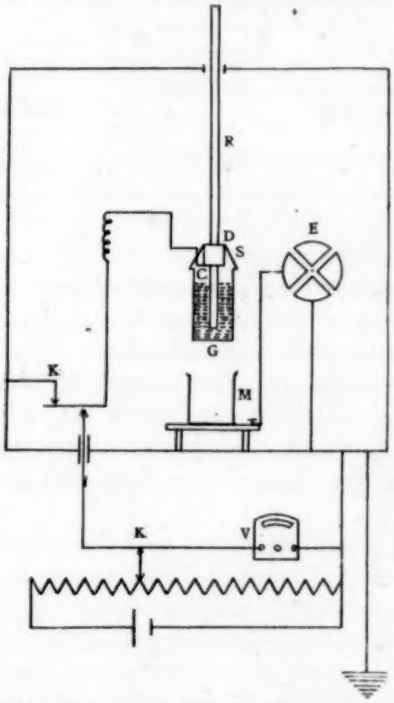
BY PHILO F. HAMMOND, PH. D.,
University of Alberta, Edmonton South, Alberta.

Last year the writer made an attempt to determine the effect of the containing vessel upon the potential difference between a metal rod immersed in an electrolyte and the outside of the vessel; in doing this several arrangements of apparatus were tried. At the suggestion of Professor Drew, the glass vessel was supported by silk threads upon a separate stand in such a way that it did not come in contact with the metal beaker surrounding it. Later, in arranging the apparatus, for some reason now forgotten, the beaker was attached by silk threads to the movable rod and was raised from and lowered into the metal beaker at will. This led to the volta effect phenomenon here described.

The apparatus was arranged as follows (see Figure 1): A metal beaker, M, was placed upon an insulated metal disc connected to a quadrant electrometer, E. A rod, R, was placed in supports so that it could be raised and lowered at will by means of a cord attached at the top of the rod which projected through the top of the electrometer cage. A copper rod, C, 13.5 cm. long and 1.3 cm. in diameter, was attached to the rod, R, by means of a short sulphur cylinder, D, which served also as an insulator. This was shielded by a hollow metal cylinder not shown. A glass beaker, G, was attached to the rod, R, by means of silk thread, S. The copper rod, C, was earthed through a fine copper wire. The whole apparatus was enclosed in the electrometer cage. Two metal beakers were used, one of copper and the other of aluminum, both 14.1 cm. high and 10.8 cm. in diameter. The glass beaker was 16.5 cm. high and 10 cm.

in diameter. Thus the space between the metal beaker and the glass beaker was about 0.4 cm.

The apparatus was so adjusted that the bottom of the glass beaker approached within the same distance of the bottom of the metal beaker as the space between the beakers on the sides; and, when raised out of the metal beaker, the glass beaker was so far above it as to have no perceptible influence upon the elec-



trometer. The glass beaker was filled about two thirds full of copper sulphate solution, so that the top of the solution came within a few centimeters of the top of the metal beaker. The apparatus was provided with a potential divider and a voltmeter so that the null method could be used.

When the copper rod was connected to one terminal of the potential divider and the potential adjusted so as to bring the mirror of the electrometer back to zero, there was no movement of the mirror upon separating the beakers.

The results given in the table may have been affected by a static charge upon the beaker; but since the effect of such a charge would have been in one direction only, if this error did occur, it increased the readings in one case and decreased them in the other, since the deflections were in opposite directions.

The table represents the averages of the results taken from a large number of trials:

TABLE.

	With Copper Beaker	With Aluminum Beaker
Electrometer deflection at approach of glass beaker	5.02 Left	12.5 Right
Voltage required to bring electrometer mirror back to zero	—0.305 volt	+0.785 volt
Voltage required to deflect electrometer 5.02 left, or 12.5 right	+0.16 volt	—0.40 volt
Electrometer deflection at separation of beakers	10.2 Right	22.7 Left
Voltage required to deflect electrometer 10.2 right, or 22.7 left	—0.33 volt	+0.73 volt

The results recorded were averaged from the results determined under the most favorable circumstances. It was found, as in other cases of contact electrification, that the condition of the inside surface of the metal beaker greatly affected the results. The results given are from trials taken with the highest polish of the beaker obtainable with the means at hand, and they are, therefore, larger than those taken when the beakers were not so well polished.

With the rod not grounded, and with the rod entirely removed, the results were the same in general, but much less in magnitude. With the rod alone, the glass beaker and electrolyte having been removed, the deflections were so small as to be entirely uncertain. After considerable time was spent in getting rid of all static charges upon the glass beaker, it was found that it alone could be raised and lowered into the metal beaker without affecting the electrometer in the least.

Trials were taken with the outside of the aluminum beaker completely wrapped and bottom covered with sheet copper, and with the copper beaker wrapped and covered with sheet aluminum, but the results were not changed in the least by this process.

The results of this experiment may not have any scientific value, but they may be of interest to those physicists who take pleasure in amusing themselves with experiments on contact electrification.

This work was done in the physics laboratory of Leland Stanford Junior University. The writer is indebted to Professor Drew and to Mr. Ulrey for suggestions.

THE CONSCIOUS DEVELOPMENT OF SCIENTIFIC IDEALS IN SECONDARY SCIENCE EDUCATION.

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The natural sciences fought their way into our schools on the ground that they could provide sufficient formal discipline to endow individuals with an "intellectual culture" such as was thought to be secured by a study of the classics. Judging from the grain of the wood in the platform of the educational party which until recently was in power, it does not seem likely that the natural sciences or any other "uncultural" subject could have gained admission to the classical fraternity formerly in charge of educational administration, had they sought entrance on the basis of being able to contribute in practical, specific ways to the production of the socially efficient individual. Having been initiated, however, it was a case of "When in Rome, do as the Romans do." They were forced to copy the methods of the classics. They were challenged to furnish the mental discipline necessary for the formation of "generalized habits" and other "generalized" functions. Furthermore, they gladly accepted this challenge. The results, in the field of science instruction, of the use of these methods and of the acceptance of this challenge are too well known to warrant description here.

Recent psychological research has struck so many blows at the old doctrine of formal discipline that we have come to view it in about the same light as the small boy did the vacuum when he said, "A vacuum is something with nothing in it." Our pet ideas—that science laboratory work increases the general observational ability of the pupil, that the power of memory will be strengthened by the discipline our instruction exacts, that when the pupil has finished our science course he will have a general faculty for attending to business in almost any profession he enters, that we have increased his general ability to reason—these ideas are not much in harmony with those of Thorndike when he says that "the mind is by no means a collection of a few general faculties, observation, attention, memory, reasoning, and the like, but is the sum total of countless particular capacities, each of which is to some extent independent of the others—each of which must to some extent be educated by itself. The task of teaching is not to develop a reasoning faculty, but many special powers of thought about different kinds of facts. It is not to alter our general power of attention, but to build up many particular powers of attending

to different kinds of facts."[1] Also: "Good reasoning power is but a general name for a host of capacities and incapacities, the general average of which seems to the namer to be above the general average in other individuals."[2]

The new doctrine of mental discipline has not yet been completely formulated. One respect in which it differs from the old theory is that mental training is not wholly general; primarily, it is specific. In addition to what has already been quoted in support of this belief, we quote Mann as follows: "The fundamental education of man was secured from his relations with nature, ages before schools were invented; yet nature never forces on men problems that are just made up to be problems, and that have no further significance. The problems of nature arise when some particular individual, impelled by motives and feelings of his own, undertakes to accomplish some specific thing in the perfectly definite situation in which he finds himself at the moment placed. The discipline that he gets in solving the problem comes from his own motivated efforts to master the difficulties which obstruct his path, but which are integral parts of the situation as a whole. Hence discipline and the training that results from it are not vague and general processes but specific and definite results of the interactions of the specific elements of specific situations."[3]

If we accept the view that reasoning is not a general faculty but is the sum total of many particular capacities, we must conclude that a mind trained to reason well with the specific elements involved in physics will not necessarily reason well when confronted with the specific problems encountered in trying to sell life insurance to a gruff old bachelor. There is no guarantee that the student of biology, who has trained certain particular observational capacities by looking at specimens through a microscope, will be unusually skillful in the detection of spurious coins when performing the duties of a teller in a banking institution.

When we proceed to outline a plan of education in which the attempt is made to apply the principle that training is specific in part, and therefore part of our task of teaching is to develop countless particular mental capacities, it may seem that at least three things must be done with reference to each individual to be trained. First, predict every specific situation in which the pupil

[1] Thorndike, *The Principles of Teaching*, p. 240.
[2] Thorndike, *Educational Psychology*, p. 187.
[3] Mann, *The Teaching of Physics*, pp. 183–184.

will eventually find himself. Second, determine all of the inherent specific elements of each specific situation. Third, develop a particular mental capacity for dealing effectively with each specific element previously determined.

Such a plan is so obviously impractical and so well-nigh impossible that it reminds one of Ford's plan to stop the war in Europe. This plan of education is as ultraspecific as the old doctrine of formal discipline was ultrageneral. It is suggested for the purpose of contrast, and the writer does not wish to imply that it is a strict interpretation of the philosophy of Thorndike, Mann, or any other modern educator.

But the fact still remains that training is primarily specific. Is it possible for the particular training, secured by a person in a given definite situation, to be of any value to him when placed in a different definite situation? Can any specific training exert a general influence on the reactions of an individual to the stimuli of his environment? The conditions under which training may be transferred from one situation to another are stated by Thorndike as follows: "One mental function or activity improves others in so far as and because they are in part identical with it, because it contains elements common to them. . . . Of the millions of situations with which life confronts us, many are duplicates, many are identical in important features, and still more have something or other in common. One business is in part identical with another business; the sciences overlap; the poet and the musician have somewhat the same task; the concrete habits adapted to life in the country are not all useless in the city; the situations of school are not much like those of the factory or farm, but they are not totally different; . . . These identical elements may be in the stuff, or in the attitude, the method taken with it. The former kind may be called identities of substance, and the latter, identities of procedure."[4]

Spencer's definition of science as "classified knowledge," if regarded as a complete definition, reminds one of the idea we once had that, at the end of the course in zoology, a high school student should be able to classify the bumps on the head of an "insectus mosquitos." That science means method as well as subject matter is generally acknowledged at present. Dewey says: "In order both of time and of importance, science as method precedes science as subject matter."[5]

[4] Thorndike, *The Principles of Teaching*, pp. 243–244.
[5] Dewey, *Science*, January 28, 1910, p. 125.

The most important problem of secondary science administration is to provide that training both in the "stuff" and the "procedure" of science which will be likely to function most frequently in the lives of the largest number of our pupils. The extent to which this training is transferable depends very much on the number of identities of both subject matter and method which are possible to exist between the training and any present or future definite situations in which the pupils find themselves placed.

At present, with respect to subject matter, excellent progress is being made in the solution of this problem of teaching the natural sciences in such a way that our pupils secure transferable training. Textbook writers are offering such books as, *Applied Electricity*, *Civic Biology*, *Household Chemistry*, and the like. Even though a writer is still conservative enough to label his product *An Elementary Chemistry*, the content is "practical." Every representative of the schoolbook companies can "talk the thing" like a veteran. Parents of pupils and school patrons in general have repeatedly insisted that we teach more things which will function to a good advantage in the lives of those whom we teach. Every science teacher has already signed, or intends to sign, the little pledge, "I will earnestly strive to bring my science close to the daily lives of my pupils." This pledge has about as many interpretations as there are methods for measuring the electrical resistance of "a wire." In the laboratory, instead of assigning an experiment whose object is to determine the specific gravity of "a substance," we are asking the question, "What is the specific gravity of the milk and cream obtained from your milkman?"

These things are characteristic of the present tendency to break away from subject matter which is general, such as "a substance," and use "practical" subject matter which is specific enough to get educative reactions from the pupils. By "practical" subject matter we mean that kind which has many elements in common with the definite life situations in which most of our pupils are placed at present and will likely be placed in the future. The vocational significance of this tendency is worthy of our serious consideration. Of a broader significance is the idea that in order to be a truly efficient individual, one must possess enough "environmental intelligence" to interpret with a fair degree of satisfaction some of the common phenomena of both physical and biological experience. So, instead of teaching the chemistry which a chemist should know

to all of our pupils, we try to select the promising chemists and cultivate them carefully, and attempt to teach the majority of our pupils that chemistry which will probably function in the lives of average individuals. And so it is with the other natural sciences.

At present it seems that much more progress is being made in our instruction in science as subject matter, than in our instruction in science as method. It is true that if a questionnaire is conducted with reference to aims in science instruction, many replies are received containing statements relative to "a scientific attitude" and "the scientific method." Admitting this, it still seems that we science teachers have been too apt to think that if we have given reasonably good instruction in subject matter, the intrinsic values of science as method will somehow "soak in" by some general, unconscious process. Of course, this is the old idea of formal discipline at work again. We seem to have overlooked the fact that training is specific with reference to method as well as with reference to subject matter. Our pupils must have definite ideas of what the scientific method is and of how to employ it, and unless they get these ideas consciously as a result of working with the concrete "stuff" involved in definite situations, they will get very little transferable training in the method of science. Unless they are made conscious of the technic of the process, there will not be much chance for "identities of procedure."

If we expect our pupils to employ the scientific method in the future, why in the name of just plain common sense do we not give them a chance to use it in their high school science work? The world has always had projects to be solved, and no doubt always will ask for a solution of projects, yet we seem afraid to give the project method a fair trial in our science teaching. The bravest among us are some general science teachers who are wading right in and are getting some astonishing results with project teaching. I refer to complete project teaching—that which involves both induction and deduction. Several prominent educators have recently called our attention to the fact that an individual must have the power to tackle and solve projects by the project or scientific method in order to be successful in almost any kind of work. Of course, we do not mean to imply that a high school pupil can use the scientific method as effectively and independently as an experienced research worker uses it.

In expressing the value of the scientific method, Bradbury

says: "This procedure—the sensing of a problem, the limitation and definition of the problem by experiments, the inductive formation of a hypothesis, the deductive treatment of the hypothesis to obtain its consequences, and the testing of the consequences by further experiments—is simply the scientific method, the most tremendous weapon in the intellectual armory of mankind . . . . Unfortunately, those who understand the method, and are able to use it, form a vanishing minority—hence the deplorable state of the world at the present moment, for when both parties to a controversy employ the scientific method, an irreconcilable difference of opinion is unthinkable. A student who had learned the scientific method and nothing else in his four years of high school life would have spent his time to better advantage and would be better fitted for citizenship than if he had been crammed with subject matter to the very ears."[6]

The best reason for following the historical development of science in our teaching is that by so doing we can reproduce the scientific method of the past, in connection with the scientific method of the present, in such a way that our pupils will be likely to use the scientific method of the future. Is this not highly suggestive of "identities of procedure?"

Recently, the writer asked several science teachers who are seriously trying to give instruction in science as method what reasons they had for believing that their instruction would provide transferable training. The substance of the reason given most times is: "For most pupils, subject matter is not the chief end of science education, but it is only a means to the chief end, namely, to train the pupil in scientific habits of thinking, of doing things, of getting results when placed in problematic situations. I am trying to train my pupils in correct habits of induction, of deduction, of framing and testing hypotheses, of industry, of orderliness, of observation, of attention, of comparison, etc. When a pupil has formed these habits, the problem of transferable training in method has been solved, and the pupil will quite likely bear a scientific attitude toward his environment."

But the question arises as to whether habits are transferable or not. If a pupil forms a habit of orderliness in his history work, will that habit "carry over" to his work in botany? Will a habit of careful observation "carry over" from the realm of physics to the duties of a physician? Since a habit is a specific response to a specific stimulus, it follows that the response made in situation A will not be the same as the response in situation B, unless there is

[6] Bradbury, SCHOOL SCIENCE AND MATHEMATICS, December, 1916.

the same specific stimulus in both cases. If the specific stimulus in case A is the same as the specific stimulus in case B, evidently the situations are identical. This leads us to the conclusion that a habit formed in one situation will not function in a different situation. If it would function in different situations, it would be a "generalized habit"—one that would be a specific response common to several different stimuli. Bagley says: "It is clear that, so far as a 'generalized habit' is concerned, the term is a psychological absurdity. The very essence of a habit is the specific character of its response. An habitual adjustment is a definite reaction called forth by some specific stimulus or combination of stimuli, and if habit were capable of being generalized the utility of judgment or conscious adjustment would be greatly diminished."[7] This belief, that habits are not transferable, is also supported by the results of recent experimentation in the field of educational psychology.

However, the science teacher who is trying to give instruction in science as method, by training his pupils in many desirable specific habits, is more efficient than the one who lazily relies on the "soak in" process. Even though we accept the psychological impossibility of "generalized habits," many of us still believe that something in method does "carry over" from definite situations to other situations which are not identical with those in which the training was secured. We have actually observed this kind of a transfer to take place, both in the cases of others and in our own cases. If we can discover the conditions under which such a transfer takes place, we ought to be able to place our instruction in science as method on a still more efficient basis than if we are satisfied to call the task completed when training has been given in the previously mentioned desirable specific habits.

The theory of transferable generalized ideals offers a solution to this problem. "Judgment may connect and establish a functional relation between two specific habits. What I carry over from my school work to my farm work is not a generalized habit of work, but a generalized ideal of work. It is something that functions in the focus of consciousness and hence cannot be identified with habit, which always functions either marginally or subconsciously. . . . If I had acquired a specific habit of work in one field without at the same time acquiring a general ideal of work, my acquisition of a specific habit in another field would probably not be materially benefited."[8]

7 Bagley, *The Educative Process*, pp. 204-205.
8 Bagley, *The Educative Process*, pp. 212-213.

"An ideal is a type of condensed experience. . . . As a condensed experience, it functions in the process of judgment. It serves as a conscious guide to conduct, especially in novel and critical situations. It functions in the initiation of specific habits, and such habits once formed may be said to harmonize with the ideal; but ideals themselves do not function as habit, although the judgments that are based upon them may often be of the 'intuitive' type."[9]

Ideals are not developed by the "soak in" process; they are developed consciously. "Unless the ideal has been developed consciously, there can be no certainty that the power will be increased, no matter how intrinsically well the subject may have been mastered."[10]

However, we should note one precaution. To quote Bagley again: "The development of an ideal is both an emotional and an intellectual process, but the emotional element is by far the more important."[11] The precaution is to actually say very little or nothing about the emotional part of the process while making the pupils conscious of both elements of it, for, as Colvin has pointed out, "It may be that intellectualizing what ought to be an emotional attitude is a dangerous procedure. It is a well-known fact that the examination of an emotion tends to destroy it."[12] It is at this point that the personality of the teacher plays, or may not play, such a dominant part in the development of ideals, by indirectly supplying the necessary emotional coloring in such a way that the pupils are conscious of it. "A conscious exhortation to enjoy any given emotion ends disastrously. Feelings seem to be controlled by the situation as a whole."[13]

Some ideals which should be developed by a study of the natural sciences are those "of suspended judgment, of open-mindedness, of just weighing of evidence, of impartial observation, of impersonal judgment, of trying to get at all the facts,"[14] and of seeking for an interrelation of facts and phenomena. Can you imagine the extent of the increase in the social efficiency of a nation if only one-fourth of its people were to be consciously guided in conduct by these scientific ideals, to say nothing of the influence of such ideals as may be developed by a study of subjects other than the natural sciences?

In the light of the preceding discussion, our training in science

9 Bagley, *The Educative Process*, pp. 222–223.
10 Bagley, *The Educative Process*, p. 216.
11 Bagley, *The Educative Process*, p. 223.
12 Colvin, *The Learning Process*, p. 245.
13 Mann, *The Teaching of Physics*, p. 192.
14 Mann, *The Teaching of Physics*, p. 191.

as subject matter must deal with "practical" content, the word "practical" being used here with the same meaning as given in a preceding paragraph; our training in science as method must be both specific and general. It must be specific in the sense of developing a very large number of particular mental capacities for making use of the scientific method; it must be general in the sense of consciously developing several generalized scientific ideals by means of establishing functional relations between particular mental capacities previously developed. Not until we do these things will our pupils receive the largest amount of transferable training.

It would be unwise to set aside one day solely for the study of subject matter, the next day for the study of the scientific method, and a third day for the development of generalized scientific ideals, for the simple reason that, in most life situations, these three elements do not function independently but are closely interwoven. Neither should a science teacher spend his time trying to plan a teaching unit so that it is exactly one-third subject matter, one-third scientific method, and one-third scientific ideals. The point is that each of these three elements should be represented in every teaching unit, whether that unit occupies one or ten days' time.

As early as possible in any science course, I attempt to introduce the scientific method in connection with "practical" subject matter. Likewise, each scientific ideal is brought before the pupils just as soon as it can be done in a natural way. Then the pupils and teacher prepare an outline of the formal steps of the scientific method and make a list of scientific ideals. During the remainder of the year, each teaching unit is a project to be solved by the scientific method. The teacher's duty, or privilege rather, is threefold; first, to use a little common sense in the selection of each project; second, to help the pupils to sense and define the problem, to inductively frame hypotheses, to deduce the consequences of hypotheses, and to test these consequences; and, third, to lead the pupils to feel and "live" some scientific ideals. This threefold duty is very suggestive of supervised study —a feature certain to be found in the high school of tomorrow. Experimentation is made whenever necessary. We are very fortunate in having our schedule so arranged that we may have laboratory work on any day or days of the week without interfering with the work of other departments. We have ignored the advice of the educational physician who, regardless of the

patient's condition, prescribed two tablespoonfuls of laboratory work and three teaspoonfuls of recitation work per week.

The high school period of adolescence is undoubtedly the best time for the development of ideals. The personality of the teacher is perhaps the most important factor in this process, and the problem of the adaptation of this personality to the composite personality of the class and to the individual personalities of the pupils must be solved by each teacher, and not for him. He must discover for himself how he can best provide that abundant inspiration and emotional spirit necessary for the conscious development of ideals. Therefore I refrain from laying down specific rules to be followed.

However, the following example is offered as an illustration of the nature of the teaching unit which should be used occasionally to reënforce the daily personal influence of the teacher.

Project: "Perhaps there is a lift pump in the kitchen of your home. How and why does it work?" One pupil was asked to write a list of scientific ideals on the blackboard, although no direct reference was made to this list during the recitation period. At the same time another pupil was asked to copy a diagram of a lift pump on the blackboard. Meanwhile the remainder of the pupils were asked to study the action of the valves. A brief discussion of the valves and their action followed. Soon this problem was sensed: "Why does the water rise in the pipe?" Although I have never appeared in a Belasco production, I took it upon myself to put on a play in two acts, in which I impersonated three characters—Aristotle, Galileo, and Torricelli. In the first act I took the part of Aristotle trying to solve this problem by his method of speculation with innate ideas. This act ended with the answer that "Nature abhors a vacuum. Therefore the water must rise in the pipe." After a brief intermission the second act was on, and I was taking the parts of Galileo and Torricelli, respectively. In this act, my lines, along with the experiments performed, depicted the method used by Galileo and his pupil, and of course a more scientific answer was found. During the "show," I tried very much to contrast the attitude of Aristotle with that of Galileo. The end of the second act was the end of the recitation, and nothing more was said in class about the lift pump until a few days later when the following questions appeared as part of a written test: "Draw a diagram of a lift pump and explain how and why it works. Contrast Aristotle's scientific attitude with that of Galileo. Name, giving reasons for your selection, at least two scientific ideals which probably influenced Galileo and Torricelli in their work with the lift pump."

THE PURPOSE AND CONTENT OF HIGH SCHOOL ARITHMETIC.[1]

By Byron Cosby,

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The purpose of the high school arithmetic class, along with other high school subjects, is to help boys or girls to find themselves. It is to help the backward boy throw off the early or primary interests, to leave forever the weighted interests except as ideals, and find himself in the social organization. But one cannot teach others how to fit into the social organization if he has not learned the rules of the game so well that he is able to take away as well as to give. The high school boy and girl with the spirit of selfishness, the lack of discrimination, the inability to differentiate, must have their problems so grouped that they see some relation between the problem and their life and ambitions. They are not looking entirely to the future, but for the most part to the present. Not many boys have decided upon a craft. The best way to help the high school pupil to put aside the childish things and fit into the social groups of the college and normal school, and to respect truth, knowing that truth will give freedom, is to help him in terms that he understands and in units of measure that he wants to work with. He needs to be told the principles that certain crafts or professions depend upon. The high school student measures his magnitudes in new dresses, new ties or other articles of wear, in automobiles, in parties, and in dollars. Our task is, then, to help him organize his interests and then advance to the ideal by relating these problems to the real problems in life. The aim is to help the student to become financially, socially, morally, physically, and ethically efficient in order that he may be useful to himself and to others and to be happy when alone and when with others.

The student is to be taught that the life in the schoolroom and outside are the same, and that the whole is a democracy where no one can do the total thinking for all, and where every one must contribute his part to the communal information and knowledge. Our quest for practicability must not lose sight of an inherent desire for conquest. The child has a right to demand that he have a chance to think.

The content of the high school arithmetic is a reproduction of those experiences that the race has found valuable or is to find valuable in the near future. It not only must reproduce those

[1] From a paper read before the Mathematics Section of the Missouri State Teachers Association.

experiences but must reproduce them in their developed setting and in terms that one can understand and appreciate. The experiences that are worth while ordinarily happen or occur as a unity or a continuity, and have a decided place in the world's arrangement. Again experiences happen in large blocks and not in so many pages or in so many exercises. A problem in the world's activities happens through long periods of time and is so complicated that many activities are touched and many situations developed. This means that the teacher of high school arithmetic must have experienced human activities in the way that they happen in the world and not as bits of hash, memorized from some book without the human or social setting. It means that the high school teacher of arithmetic must have recognized the various problems in the present-day world and have ingenuity enough to organize and patience enough to work until the organization is effected.

We discovered several years ago that the proper way to study the classics in French and English was to take the complete drama or story and study it as a whole. Of course there are still some who think that to teach an English classic means to dissect it and label every nerve and sinew with some name that any human being with respect for himself does not care to remember. But in spite of the fact that in most of the teaching of the classics they have been taught very successfully as completed wholes, we have been slow to teach our arithmetic as a continuous subject, and still find in our newest texts on arithmetic that the author has dissected and labelled every problem, not paying any attention to whether or not the experience has a place in the world and, even though it has a place, whether or not at the time, it is useful, beautiful, or interesting.

In order to get a high school pupil to understand the problem in his language and in terms of his own selfish undifferentiated interests, I think one might show him the economics of education, how to build a house, operate an automobile, or any other of the reasonable experiences that the average boy or girl goes through almost any day in the year. The young man wants to know how he can get rich, how he can save energy, how he can receive rewards without much effort, how he can avoid penalties, how he can understand the machines around him, how he can make his play or recreation bring him greater happiness, how he can please his friends, how he can discover and operate the working principles of all forces and anything else that happens in his

vicinity or that he hears of or reads about. He wants to do tomorrow what his heroes are doing today, only he wants to do it with greater cleverness, ease, and economy. He wants to improve; his ambitions and ideals are high.

The problem is more attractive when the child sees the need or the relation. A series of problems, not exercises, showing the value of an education from the arithmetic side as a factor in the making of a living, will help the student to see the need of studying those things that will make life richer and fuller now and in the future. The problem should be one that gives the student the same experience in the working that he will need in attacking a problem in his business or play in after life. An economic problem stated in arithmetical notation makes clear the fact more readily than any other notation. The waste of labor, capital, material, thought, taste, and other human elements can be measured in dollars. If idleness can be measured in dollars and waste of material be shown to be a depreciation in capital, the student has experienced a problem of evaluating labor and capital.

Does it pay from a financial standpoint to get a high school education? Does increased financial income up to a certain point make a man more efficient, more useful and more happy? Are you of greater service to yourself and to society if your earning power is increased? If you are not able to earn enough to support yourself, provide for the needs of your family, promote the general or communal welfare, build up a library or other working tools, travel, and have the other cultural and useful conveniences, can you be of the highest use to society or make your life the most attractive to yourself, your family and your country? A man with a common school education is supposed to be worth in earning power expressed in dollars one and a half times as much as the illiterate man; that is, he earns one and a half times as much, while the high school graduate earns twice as much and the college graduate four times as much. And there are other things, such as appreciation, pleasure, culmination of ideals, and ambitions.

Statistics taken from the United States Census may help us to see the need of trying to increase our earning power. Some one states that sixty-six out of every one hundred persons dying in this country die without an estate. Only two per cent may be classed as earning sufficient to be socially efficient. Ninety-eight per cent are living off of daily wage, are supported by rela-

tives, or are living on inherited property. Ninety-seven per cent of all people reaching the age of sixty-five are dependent upon others for support. With the economic as a basis to start with, the ideal of unity, the characteristic curiosity, the assembling or synthesizing, and analysis let us organize a problem.

Instead of choosing several so-called problems but in truth exercises about lumber measure, cement, plastering, wall papering, painting and so on, take the building of a house. It involves all of the tastes and instincts of the class, no matter how varied the membership or the previous experiences of the class. One student is interested in drawing the plans, another in excavating and removing the dirt, another in the mixing of the cement, and another the laying of joists and the building of the walls. While some of the students have found themselves in this kind of work, others are working on the amount of heavy lumber needed, others on the various kinds and quantities of lumber to be used, others on the millwork, others hardware, others heating plants, others systems of lighting, and others on papering, painting, and interior decoration. Each solves the entire problem, but only as he is a member of the class and only in the way that he contributes to the whole. Each takes for his work the part that he is interested in, and has terms or units of measure for expressing himself and has had experiences in, either personal or through reading or listening to others. I have found in trying such a problem in our Practice School that every boy can be interested in his part. A part of the class took up the organization of the forces necessary to build the house, looking up the abstract of title, the deed, the deed of trust or mortgage, the check for paying and the promissory note accompanying the deed of trust and gave the information to a class that was interested in the whole problem and needed this particular work to help to unify the whole. Each received only that for which through experiences and work he was ready for. The girl with a liking for stencilling and designing worked eagerly on her stencil borders for the dining room, the living room, the parlor, and the library, drawing her illustrations to scale and doing exactly the same problem that the boy did in determining the amount of lumber needed. She had to measure and do it with as fine a degree of nicety as the boy who wanted to know the amount of studding. The reports that each member of the class made to the whole class were attractive, because the one reporting put his life, his interests, his energy, and his investment into the problem.

As another type of a problem meeting the manufacturing situation, take the automobile industry. Here we need to assemble the problems of expense for labor, capital, depreciation, material, upkeep, interest on investment, replacement value, as new machinery is invented and a dozen other items that must necessarily enter into the operating expenses of a manufacturing business. The student also has to find out the cost of marketing, the cost of delivering to station or shipping depot, the railway charges, the cost of billing out, the cost of follow up in case of failure to deliver, the retaining of trade, the cost of salesmen, the overhead charges, the publicity or advertising expenses, the profit, and everything else that might enter into the business. Most of our failures in business, and Dun's and Bradstreet's agencies report a very large percentage, are due to the fact that business men rarely know the actual cost of anything. They may know the initial cost, but the advertising cost, the overhead charges, the drayage and other items are lost track of; and consequently many things are sold at a price actually below the cost of production. These are unit problems and have a real value and should be found in the high school arithmetics. Such a problem might take many weeks to solve, but when solved it has actual value. In any and every neighborhood such problems abound. In the country are found the farmer, the carpenter, the blacksmith, and the molasses maker, and in the nearby towns almost every sort of business.

As a special or type lesson on one of these problems we took the furnishing and decorating of an ideal dining room. In this problem a floor plan is drawn to scale, the height of ceiling decided upon, the plan of the floor, whether bordered with oak, or carpeted. The painting and finishing called for the relative cost of paint, calcimine, paper, varnish and floor wax. The question of having the floor border of oak, of matting or of plain, varnished yellow pine came up for decision. Then came the furnishing of the room. The number of pieces and quality of material needed, as the number of chairs, the number of pieces of table linen, the number of the different pieces of silverware, the amount of the other things found in the dining room, the pictures on the wall, and a general plan of marking the table-linen with letter or monogram. After the goods were decided upon, furnishings were decided upon, the local merchants and merchants in other towns were asked to make bids. If ordering from other towns, the question of postage, freight, parcel post

and express rates came up, as well as the cost of the money order or draft. The letter was written for quotation, the draft written out and the order sent in the regularly accepted manner. This problem gave each girl a chance. She put into the problem whatever she wanted to, and yet had at all times to make or secure from some source her data, and then organize the data into terms that she and the other members of the class could appreciate. It is needless to say that each understood the problem and worked with an aggressiveness that cannot be equalled by the old plan of finding the least common multiple, or spending several hours on simple interest problems, or working for months on denominate numbers.

Another interesting problem was on the cost of an elementary education. It was surprising how much the cost was and how eagerly the children looked for material and brought to light the most unexpected material and decided that such material belonged to the problem and had a part in its solution.

The high school student is inexperienced in synthesis; he organizes with difficulty; and as he has not had the experience of trying to put into words his activities and experiences he interprets his problem slowly and with difficulty. He needs experience in organizing, in synthesis, and he gets this experience only in practice. He can get this experience or practice in a natural, wholesome manner only by collecting his material and working it over into the problem. We understand the things that are written in terms of our experiences and in our language, even though the grammar of that language may not always be correct. The child's problem must be stated in terms of his experience and knowledge. The trouble at the present time and with nearly every text is that the exercises are ones that the child, and oftentimes the adult, have never met and are stated in terms that no one understands, or if understood do not interest because they are so far removed from life or present-day activities. Our conclusion is, then, that the boy and girl must make the content of arithmetic in terms of their experience, in language that they understand, in the large units of actual everyday happenings, far removed from isolated or strained situations, and in present time. The child wishes to be 100 per cent efficient in some one thing and to know many things well or partially.

If arithmetic is to be retained in our high schools it must be retained on account of its simplicity and usefulness. Its simplicity will be reached only when the notation is such that the

ordinary person can understand it without having previously taken a course in physics or the other high school subjects, and it will be useful only when we repeat in the schoolroom those experiences and those only which the race has found helpful or expects immediately to make useful; these experiences are those found in the large blocks or units of human activity. No isolated, formal, predigested, strained, dried, and dwarfed exercises have a place in the schoolroom. Arithmetic is not a dry subject. Arithmetic not only must be simple and give to us an understanding of those experiences that the race has or will find useful, but it should be such a subject as to give to the child the next step in his human experiences. The schoolroom is a part of the life of the child, and as such it should give human experiences that are valuable and at all times give them in the most pleasant and economical manner possible.

A NOTE ON SOLVING AN IRRATIONAL EQUATION.

By Albert Babbitt.

University of Nebraska, Lincoln.

I. The usual method of solving an irrational equation consists in clearing the equation of radicals. It is the object of this note to illustrate another method of solving an irrational equation all of whose terms are surds of the second order.

Consider the equation: $\sqrt{3x^2-5x+7}+\sqrt{3x^2-7x+12}=3$ (1)

Find the difference of the two radicands, i.e., write the identity

$$(3x^2-5x+7)-(3x^2-7x+12)=2x-5, \text{ or}$$

$$(\sqrt{3x^2-5x+7})^2-(\sqrt{3x^2-7x+12})^2=2x-5. \quad (2)$$

Dividing (2) by (1), we obtain $\sqrt{3x^2-5x+7}-\sqrt{3x^2-7x+12}=\frac{2x-5}{3}$ (3)

Adding (1) and (3), we get $2\sqrt{3x^2-5x+7}=\frac{2x+4}{3}$ (4)

Squaring (4), we have $3x^2-5x+7=\frac{x^2+4x+4}{9}$, a quadratic equation in x.

It is seen at once that if in the right hand member of (3), x should appear in the denominator, or if x should appear in the numerator to the second, or higher power, then after squaring (4) and simplifying we should obtain an equation of the fourth or higher degree which in general cannot be solved readily.

We therefore state the following rule:

An irrational equation can be solved by the method here illustrated only if the *quotient* obtained by dividing the difference of the two radicands on the left by the right hand member, *is a polynomial in x of degree not higher than the first.*

II. If an equation contains surds of the third order, the formula $(a\pm b)^3=a^3\pm b^3\pm 3ab\,(a\pm b)$ will be found useful.

Let it be required to solve the equation $\sqrt[3]{x+45}-\sqrt[3]{x-16}=1$.

Letting $\sqrt[3]{x+45}=u$, $\sqrt[3]{x-16}=v$, the given equation may be rewritten thus:

$$u-v=1.$$

Cubing by above given formula, and noticing that $u-v=1$, we get, after replacing u and v by their values in x,

$(x+45)-(x-16)-3\cdot 1\cdot \sqrt[3]{(x+45)\ (x-16)}=1$, or

$61-3\sqrt[3]{(x+45)\ (x-16)}=1$,

whence, $\sqrt[3]{(x+45)\ (x-16)}=20$.

Cubing, and solving the resulting quadratic equation we find $x_1=80$, $x_2=-109$. Both roots satisfy the given equation.

This method can be frequently employed in solving equations which involve three surds of the third order. Thus, the equation $\sqrt[3]{(8+x)^2}-\sqrt[3]{(8+x)\ (8-x)}+\sqrt[3]{(8-x)^2}=4$, can be solved by the method here illustrated.

A NOTE ON THE LAW OF SINES.

By Albert Babbitt.
University of Nebraska, Lincoln.

The object of this note is to show how to deduce the Law of Sines from the Law of Cosines.[1]

From the Law of Cosines we have

$$\text{Cos } A=\frac{b^2+c^2-a^2}{2bc},$$

$$\text{Cos } B=\frac{a^2+c^2-b^2}{2ac},$$

$$\text{Cos } C=\frac{a^2+b^2-c^2}{2ab}.$$

Hence, $\sin^2 A=1-\cos^2 A=1-\left(\frac{b^2+c^2-a^2}{2bc}\right)^2=\frac{(2bc)^2-(b^2+c^2-a^2)^2}{4b^2c^2}=$

$$\frac{(b+c+a)\ (b+c-a)\ (a+b-c)\ (a-b+c)}{4b^2c^2}=$$

$$\frac{4s\ (s-a)\ (s-b)\ (s-c)}{b^2c^2}, \tag{1}$$

where $a+b+c=2s$.

Similarly, $\sin^2 B=\frac{4s\ (s-a)\ (s-b)\ (s-c)}{a^2c^2}$, (2)

$$\sin^2 C=\frac{4s\ (s-a)\ (s-b)\ (s-c)}{a^2b^2}. \tag{3}$$

Dividing (1), (2) and (3) by a^2, b^2 and c^2 respectively and extracting square roots, we get

$$\frac{\sin A}{a}=\frac{2\sqrt{s\ (s-a)\ (s-b)\ (s-c)}}{abc},$$

$$\frac{\sin B}{b}=\frac{2\sqrt{s\ (s-a)\ (s-b)\ (s-c)}}{abc},$$

$$\frac{\sin C}{c}=\frac{2\sqrt{s\ (s-a)\ (s-b)\ (s-c)}}{abc}.$$

Hence, $\frac{\sin A}{a}=\frac{\sin B}{b}=\frac{\sin C}{c}$ (Law of Sines).

Note. It can be shown that the relation $A+B+C=180°$ follows from the Law of Sines and Law of Cosines.

Express in the Law of Cosines ($c^2=a^2+b^2-2ab\cos A$) all the sides in terms of one angle (say, C), using the Law of Sines, and simplify, thus obtaining the relation

$$\cos^2 A+\cos^2 B+\cos^2 C+2\cos A\cos B\cos C=1.$$

Hence it can be shown that $A+B+C=180°$.

[1]Carnot (1753–1823) was the first to show this.

RESEARCH IN CHEMISTRY.

Conducted by B. S. Hopkins.

University of Illinois, Urbana.

It will be the object of this department to present each month the very latest results of investigations in the pedagogy of chemistry, to bring to the teacher those new and progressive ideas which will enable him to keep abreast of the times. Suggestions and contributions should be sent to Dr. B. S. Hopkins, University of Illinois, Urbana, Ill.

THE PERIODIC SYSTEM AND THE STRUCTURE OF ATOMS.

By D. A. MacInnes,

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Until recent years the view was pretty generally held that the atoms are the ultimate particles into which matter can be divided, and it was believed that there are just as many different kinds of matter as there are elements. It is true that the periodic system and the closeness with which many of the atomic weights approach whole numbers hinted at some relationship connecting the elements. Occasionally some daring spirit would make the suggestion that the atoms are built up of some common substance or substances. Such suggestions were, however, always dismissed as mere dilettante speculation. The reasons for this attitude on the part of scientists are not difficult to understand. Many atomic weights are not exactly whole numbers, and the variations cannot be explained by experimental error in the determinations of these quantities. Chlorine, whose atomic weight is 35.45, magnesium, with a value of 24.32, and most of the atomic weights above 60 deviate markedly from whole numbers. It is also true that hydrogen has an atomic weight of 1.0075, and not exactly 1.000, as would be expected since it would, presumably, be an important constituent of the surprising number of elements whose atomic weights are exact multiples of 1. And although the chemical properties of the elements are found to change in a periodic

manner with the atomic weights in nearly every case, the chemical properties require that argon, atomic weight 39.88, should be placed in the periodic arrangement before potassium, atomic weight 39.1. There is a similar discrepancy in the case of iodine, the chemical properties of which place it after tellurium, which has a higher molecular weight.

Recent researches have thrown a flood of light on the problem of the meaning of the periodic system, although all the difficulties are by no means cleared up. Speculations as to the relationship connecting the elements, and the architecture of the atom, are no longer frowned upon. They are the present scientific fashion.

The greatest factor in the formation of the present explanation of the periodic system and our present theories of the structure of the atom has been the study of the phenomena of radioactivity. As is well known, radium produces three types of radiations, the alpha, beta, and gamma rays. The beta rays have been shown to be streams of electrons, and gamma rays to be similar to X-rays. In 1903 alpha rays were proved, by Ramsay and Soddy*[1], to be helium atoms carrying two positive charges. Shortly after this, uranium and thorium were also shown to be radiating charged atoms of helium. Here we have evidence that some of the heavier elements, previously supposed to be eternal, are breaking down. When a helium atom leaves a radium atom, an atom of an inert gas, niton, (or radium emanation) remains. That this decomposition is not the spontaneous decomposition of a chemical compound is evident from the fact that the rate at which this decomposition occurs is unaffected by any physical process under our control, and also from the observation that radium, niton, and helium all have places in the periodic system, niton being a previously unknown element in the family of inert gases. It is also well known that uranium is the first of a series of decomposition products passing through radium and niton and ending with lead. The series, omitting branch series, can be represented as on page 437.[2]

The atomic weights are given under the symbol for each element. The atomic weights of uranium, radium, and niton have been determined directly. The others have been obtained by subtracting 4, the atomic weight of helium, whenever an alpha radiation occurs. Investigators of the subject naturally wondered whether there are places in the periodic system for

(*The numbers refer to the bibliography at the end of the paper.

Ur.—> α 238	Ur. X_1—> β 234	Ur. X_2—> β 234	Ur. 2—> α 234	Ionium—> α 230
Ra.—> α 226	Nt.—> α 222	Ra. A—> α 218	Ra. B—> β 214	Ra. C—> β 214
Ra. C—> α 214	Ra. D—> β 210	Ra. E—> β 210	Ra. F—> α 210	End

all these elements. In investigating this question, several scientists simultaneously reached the very important conclusion that *when an alpha radiation occurs the resulting element has a position two "places" to the left of the parent element in the periodic system, and when a beta radiation occurs the resulting element has a position one place to the right.* Let us see how this works out for the uranium-radium system just discussed. Figure 1 represents the portion of the periodic system containing the heavier elements. For convenience the zero group is placed in

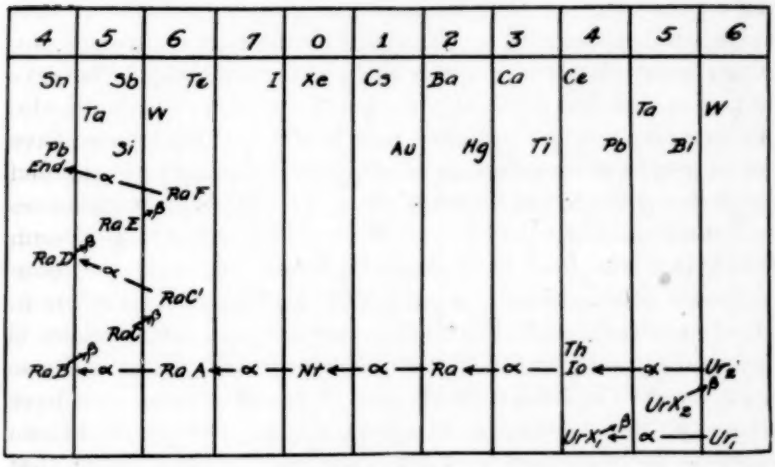


FIGURE 1.

the center. As the periodic system is really a spiral laid out on a cylinder, it is also convenient for what follows to open out the cylinder and represent portions of groups 4, 5, and 6 twice. Starting with Ur, in the sixth groups on the lower right-hand side of the figure, we see that this element gives off an alpha particle forming Ur. X_1, which in turn gives off two beta particles, forming successively Ur. X_2 and Ur. 2. It is interesting to note that Ur. X_1 so greatly resembles thorium (atomic weight

232.4), which occupies the same place in the table, that it has been found impossible to separate one from the other chemically. The two elements are called "isotopes," a name given them by Soddy. Ur. X_1, however, has an atomic weight of 234. Here we have the strange phenomenon of two elements with different atomic weights but with identical chemical properties, occupying the same place in the periodic system. Quite a number of such isotopes are known, and some consequences of their existence will be discussed below. The presence of uranium 2, isotopic with Ur. 1, is known from the fact that uranium gives off alpha particles with two different velocities. The alpha radiation of Ur. 2 results in the formation of ionium, isotopic with thorium, and Ur. with X_1. From here the disintegration series passes through the radium series, finally ending in a product isotopic with lead.

Now, although the atomic weight of radium (226) agrees with that calculated from that of uranium (238) by the subtraction of four times the number of alpha particles evolved, the atomic weight of lead cannot be obtained in this way. Five helium atoms are evolved on the way from radium to lead. The calculated value for lead is 226—(5×4), or 206. The directly determined value for ordinary lead is 207.1. This observation led to a careful examination of the atomic weight of lead from minerals containing radioactive elements. Here, in remarkable confirmation of the theory as outlined, Richards and Lembert[3] found that the lead from minerals containing radium has a decidedly lower atomic weight (206.4) than ordinary lead. Starting with thorium, there is another series of decompositions, also ending with lead. For this lead product the calculated atomic weight is 208.2. Soddy and Hyman,[4] working with lead from thorium-containing minerals, found the value 208.4. A plausible hypothesis is, therefore, that "ordinary" lead is a mixture of these isotopes, and that others of the elements whose atomic weights are not integers are mixtures of isotopes.

It is interesting in this connection to note that if we could induce each atom of lead to give off two alpha particles and a beta particle, we should have an element isotopic with gold, thus realizing the dream of the alchemists. So far, as has been stated, radioactive transformations have proved to be out of our control.

The study of X-ray spectra is another line of experimenting that has produced significant results in connection with the

interpretation of the periodic system. Light of the usual frequencies is, as is well known, spread out into its components after being directed against a grating made by scratching lines on glass or metal. These lines must, however, be ruled at distances apart of the same order of magnitude as the wave lengths of light. Gratings that will disperse light have no effect on X-rays. For this reason it was doubted whether X-rays are similar to light in being electromagnetic waves. It occurred to Laue that in crystals we have naturally occurring "gratings" composed of the rows of atoms. Experiments showed that X-rays are dispersed on passing through crystals, indicating the similarity of the rays to light. W. H. and W. L. Bragg[5] (the most recent recipients of the Nobel prize in physics) invented an X-ray spectrometer by which the X-rays can be analyzed and the wave lengths calculated. Shortly after this Mosely[6] used a form of the Bragg X-ray spectrometer to analyze the secondary X-rays emitted by different elements. When a beam of X-rays impinges on an element, secondary X-rays start from it. These secondary rays are characteristic in properties of the element which produces them. Mosely found that the secondary rays from every element consist of two types which he named the K and L radiations. He found a remarkable relationship between the frequencies of the K radiations in the different elements. If f is the frequency and K is a constant, the relation is

$$f = K(N-1)^2.$$

N in this equation is the "atomic number" of the element; that is to say, the number of the element in the order of its appearance in the periodic system. This is in general the order of increasing atomic weight except when this order clashes with the chemical properties. Allowance must also be made for three unknown elements between hydrogen and gold. A similar simple formula was found for the L series.

The next problem of interest was to determine the "atomic number" of each of a pair of isotopes, by the X-ray method. As has been observed, the gamma radiation from radioactive elements is similar to X-rays. Rutherford and Andrae[7] analyzed the gamma rays given off by Radium B, and found that these gamma rays are *identical with the secondary X-rays from lead.* Mosely's work showed that lead has an "atomic number" of 82. From the preceding discussion it would appear reasonable to suppose that the atomic number of a radioactive element de-

creases two for an alpha radiation and increases one when a beta radiation takes place. Table I shows that this is the case.

TABLE I.

Element.	Radiation.	Atomic Weight.	Atomic Number
Ra	alpha	226	88
Emanation	alpha	222	86
Ra. A	alpha		84
Ra. B	beta	214 = 226—(3 × 4)	82
Ra. C	alpha		83
Ra. D	beta		82
Ra. E	beta		83
Ra. F	alpha		84
Lead		207 (206)	82

It is seen that Ra. B, Ra. D, and lead have the same atomic number. Other workers have shown that they are chemically inseparable. Apparently the atomic number is a more fundamental property of an element than its atomic weight, since elements with as different atomic weights as is represented by the figures 214 and 207 can occupy the same position in the periodic system, and have the same chemical properties and spectrum.

A theory of atomic structure that has received much experimental support is that proposed by Rutherford[8] to account for the scattering of alpha particles in passing through matter. If radium is placed in a thin glass tube, evidence of helium gas can soon be obtained *outside* the tube. Apparently helium can pass through glass if it is in the form of alpha particles. Helium itself does not possess this property. The atoms of helium appear to be able to penetrate into other atoms if projected with sufficient velocity. Most of the alpha particles proceed through matter with but small deviations from their original direction. A very small portion of the total number, however, are deflected through large angles. This effect is, roughly, like throwing a baseball at a picket fence. The ball will go in a straight line unless it hits a picket, in which case it will be deviated widely from its original course. Rutherford's calculations show that the deviations observed in the paths of alpha particles can be accounted for if each atom has a positively charged core with a radius approximately one-thousandth of the radius of the atom. If an alpha particle penetrates into an atom sufficiently near to its core, the electric force will give the moving particle a sudden change of direction. The calculations showed further that the charge on the core is approximately one-half the atomic weight of the element. This charge is, in all probability, proportional to the "atomic number." In the light of this theory,

the factor determining the place in the periodic system, the chemical properties, and the spectrum of an element, is the net electrical charge on the core of the atom. By net electrical charge is meant the difference between the charges of the positively charged matter and negative electrons in the core. The difference of mass between two isotopes (such as lead and Radium B) is thus probably located in the core and due to charged helium or hydrogen atoms, balanced by electrons. Around the core, distributed throughout the space occupied by the atom, are electrons, probably arranged in concentric spheres.

Harkins and Wilson[9] have made some interesting theoretical investigations into the relations existing between the elements of lower molecular weight. They calculate, for instance, that the probability, or chance, that the atomic weights would come as close to whole numbers as they do entirely by accident is but one part in fifteen million. Also, the first twenty-seven elements, beginning with helium, are not multiples of the atomic weight of hydrogen by a whole number. However, when these atomic weights are examined critically it is found that they differ from the corresponding whole numbers by nearly constant percentage difference, with an average value of —0.77%. This percentage deviation Harkins and Wilson call the "packing effect," or the percentage decrease of mass when hydrogen atoms are packed together, to make, as they conceive it, more complex atoms. The regularity of this calculated "packing effect" is very striking, the values for a number of the lighter atoms being as follows: He. —0.77%; B —0.77%; N —0.70%; O —0.77%; F —0.77%; C —0.77%; N —0.77%; while the average value for the first twenty-seven elements is —0.77%. The same authors also present a table showing a possible composition of the atoms of the lighter elements, conceived to be built out of hydrogen and helium. The arrangement is shown in Table II.

TABLE II.

Group.	0.	1.	2.	3.	4.	5.	6.	7.
	He	Li	Be	B	C	N	O	F
	He	$He+H_3$	2He+H	$2He+H_3$	3He	$3He+H_2$	4He	$4He+H_3$
Theor.	4.00	7.	9.0	11.0	12.0	14.00	16.00	19.00
Deter.	4.00	6.94	9.1	11.0	12.0	14.01	16.00	19.00
	Ne	Na	Mg	Al	Si	P	S	Cl
	5He	$5He+H_3$	6He	$6He+H_3$	7He	$7He+H_2$	8He	$8He+H_3$
Theor.	20.00	23.00	24.0	27.0	28.0	31.00	32.00	35.00
Deter.	20.00	23.00	24.32	27.1	28.3	31.02	32.07	35.46
	A	K	Ca	Sc	Ti	V	Cr	Mn
	10He	$9He+H_3$	10He	11He	12He	$12He+H_3$	13He	$13He+H_3$
Theor.	40.00	39.00	40.00	44.0	48.0	51.0	52.0	55.00
Deter.	39.9	31.17	40.07	44.1	48.1	51.0	52.0	54.93

Each square contains (from top to bottom) the symbol of the element, the possible number of hydrogen and helium atoms composing it, the theoretical atomic weight, and the experimental value of the atomic weight. It can be seen that a surprising number of the atomic weights can be closely expressed by adding together small multiples of the atomic weights of helium and hydrogen. Hydrogen is here assumed to be "packed" and to have an atomic weight of 1.000. The exceptions (magnesium, chlorine, and silicon) may be mixtures of isotopes, though this is but a hypothesis and a basis for further research.

It is interesting to note that with the single exception of beryllium, the weights of the atoms in the even-numbered and zero groups in this table may be expressed as whole numbers times the atomic weight of helium. This may be the reason why hydrogen is never given off in radio-active transformations, as the more stable radioactive substances all belong to the even-numbered and zero groups.

The author's purpose in this brief sketch will be more than fulfilled if it induces any readers to go further into the subject by consulting some of the references below, where the subjects are dealt with in more detail.

[1] *Proceedings of the Royal Society. 72A*, 204 (1903).
[2] Soddy, *Radiochemistry.* (Longmans, Green & Company.)
[3] *Journal of the American Chemical Society, 36*, 1329 (1914).
[4] *Transactions of the Chemical Society, 105*, 1402.
[5] *X-Rays and Crystal Structure.* (A. Bell and Sons.)
[6] *Philosophical Magazine, 26*, 1024, and 27, 703.
[7] *Philosophical Magazine, 27*, 854.
[8] *Philosophical Magazine, 21*, 669 (1911).
[9] *Journal of the American Chemical Society, 37*, 1367 (1915).

A SIMPLE DEMONSTRATION TUBE FOR EXHIBITING THE MERCURY HAMMER, GLOW BY MERCURY FRICTION, AND THE VAPORIZATION OF MERCURY AT REDUCED PRESSURE.[1]

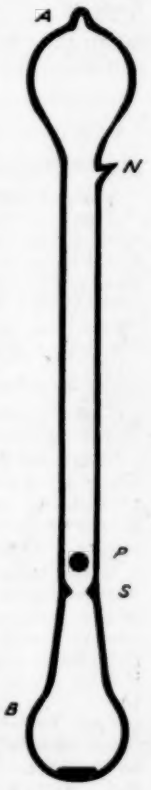
By Charles T. Knipp,
University of Illinois, Urbana.

When the pressure over mercury is reduced to that of mercury vapor only, vaporization with heat takes place at surprisingly low temperatures, and the resulting mechanical pressure

[1] Apparatus exhibited and demonstrated before the Galesburg meeting of the Illinois Academy of Science, February 24, 1917.

exerted by the issuing vapor from the mercury surface is even more surprising. The magnitude of this pressure over a surface confined in a large bulb, so that the vapor stream is not concentrated, is sufficient even at temperatures as low as 130° C. to freely support bits of cork. To make this easy of demonstration the writer has designed a tube to show the above, together with the familiar mercury hammer, and glow by mercury friction phenomena—all in one.

The tube should be about 35 cm. long by 1½ cm. in diameter, and have the usual bulb at each end that obtains for the mercury hammer. A stricture reducing the diameter to ½ cm. is placed near one end. A small quantity of mercury (about 10 grams) is put in the tube, and also a spherical pith ball about ¾ cm. in diameter is placed in the bulb farthest removed from the stricture. The tube is pumped out carefully and sealed off (the sealing-off nipple should be attached to the stem and not to one of the bulbs). It is now ready for the exhibition of the three phenomena referred to above. To show the pressure of the mercury vapor it is only necessary to hold the tube by the upper bulb (the one farthest from the stricture) over a Bunsen burner and allow it to heat gently. Soon condensed mercury vapor appears on the walls of the lower bulb and its progress up the tube is readily followed. The *bombardment of the mercury vapor lifts the pith ball* which, oscillating up and down, is forced into the upper bulb where it is violently agitated by the expanding mercury vapor stream. Removing the apparatus from the heat allows the oscillating pith ball to descend the tube until it again rests upon the stricture. At this moment if the bulb is returned to the flame the ball is again almost instantly shot upward—showing in a striking manner how sensitive the apparatus is. There is little danger of cracking the tube if care is taken not to plunge the lower bulb suddenly into the flame, and if it is allowed to cool before laying down.



The other two phenomena, i. e., the mercury hammer, and glow by mercury friction, are so familiar that they do not call for special mention here.

PROBLEM DEPARTMENT.

Conducted by J. O. Hassler,
Englewood High School, Chicago.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics. Besides those that are interesting per se, *some are practical, some are useful to teachers in class work, and there are occasionally some whose solutions introduce modern mathematical theories and, we hope, encourage further investigation in these directions. All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. In selecting solutions for publication we consider* accuracy, completeness, *and* brevity *as essential. Address all communications to J. O. Hassler, 2301 W. 110th Place, Chicago.*

Algebra.

492. *Proposed by Harry M. Roeser, Washington, D. C.*

The popular game, "shooting craps," is played as follows:

Two players place a stake. "A" throws two dice. If the sum of the spots turned up at the first throw totals 7 or 11, he wins; if they total 2, 3 or 12, he loses. If none of these points are turned, he throws again and again and wins when he duplicates the point that is turned on the first throw. He loses if, while attempting to duplicate his point, the dice turn up 7. Let it be required to demonstrate that the player rolling the dice has or has not an even chance of winning.

Solution by Bancroft H. Brown, Providence, R. I.

The player rolling the dice does not have an equal chance of winning. His probability is $^{244}/_{495}$.

There are 36 possible throws with two dice, all equally liable to occur. There are 6 ways of throwing 7 and 2 ways of throwing 11, so the "caster's" probability from these eight throws is $^{8}/_{36}$. There is one way of throwing 2, one way for 12 and two ways for 3; so the caster's possibility of losing is $^{4}/_{36}$. The chance that the play continue is $^{24}/_{36}$.

If the play continue he has an added chance to win, the value of the chance depending on the "point" turned on the first throw. The turning of this point and the turning of 7 or 11 on the first throw are independent events (mutually exclusive) and the total probability is the sum of the individual probabilities. There are three ways of throwing 4 (or 10) so if 4 (or 10) is his point there are nine of the 36 possible results in any one throw after the first which decide the game. Three of them are favorable (if he throws 4 (or 10)) and 6 are unfavorable (if he throws 7). In every succeeding play the odds are 2 to 1 against his throwing 4 (or 10), so that his total added probability from 4 and 10 is

$\frac{2x3}{36} \times \frac{1}{3} = \frac{1}{18}$, since the probability of the concurrence of two dependent events is equal to the product of the probability of one of the events by the probability that if that event occur, the other will happen also.

His added probability from 5 and 9 is

$$\frac{2x4}{36} \times \frac{2}{5} = \frac{4}{45}.$$

His added probability from 6 and 8 is

$$\frac{2x5}{36} \times \frac{5}{11} = \frac{25}{198}.$$

The sum of $^{6}/_{36}$, $^{1}/_{18}$, $^{4}/_{45}$, $^{25}/_{198}$ is $^{244}/_{495}$.

It may be worthy of note that if one die is "loaded" to always come up 6, the "caster's" probability is 7/12; 5, 2/3; 4, 7/12; 3, 7/12; 2, 1/2; 1, 5/12.

506. *Selected.*

There is some coal on a dock, and coal is running on the dock through a chute at a uniform rate. Six men can clear the dock in one hour, or eleven men can clear it in twenty minutes. How long will it take four men to clear the dock?

I. *Solution by Benjamin F. Yanney, Wooster, Ohio.*

Let d = the number of tons of coal on the dock,

r = the number of tons per hour running on the dock,

and m = the number of tons per hour released from the dock by each man.

Let t = the number of hours it will take four men to clear the dock.

Then $$4mt = d + rt, \tag{1}$$

whence $$t = \frac{d}{4m - r}. \tag{2}$$

But from the two conditions of the problem, we have, respectively,

$$6m = d + r, \tag{3}$$

$$11m/3 = d + r/3. \tag{4}$$

Solving these two equations for d and m in terms of r, we get

$$d = {}^{5}/_{7}\,t \text{ and } m = {}^{2}/_{7}\,r. \tag{5}$$

Substituting these values of d and m in (2), we get finally

$t = 5$.

Hence it will take four men five hours to clear the dock.

II. *Solution by R. M. Mathews, Riverside, Cal.*

Let a denote the amount of coal on the dock, b the amount running from the chute per hour, and t the hours for 4 men to clear the dock. Then

$$a + bt - 4t = 0$$
$$a + b - 6 = 0$$
$$a + {}^{1}/_{3}\,b - {}^{11}/_{3} = 0.$$

For these equations to be consistent

$$\begin{vmatrix} 1, & t, & -4t \\ 1, & 1, & -6 \\ 3, & 1, & -11 \end{vmatrix} = 0,$$

whence $t = 5$.

III. *Solution by D. E. Davis, Edinburg, Ind.* (*By analysis*).

Let A = the amount of coal on the dock.

B = the amount of coal which will run through the chute onto the dock in one hour's time.

Then by the first condition of the problem, 6 men can clear away A and B in one hour.

Or one man can clear away A and B in six hours.

Also by the second condition of the problem, 11 men can clear away A and $\frac{1}{3}$B in 1/3 hour.

Or one man can clear away A and $\frac{1}{3}$B in 11/3 hours.

Now the difference in time is 7/3 hours, and the difference in work is $\frac{2}{3}$B.

From the above: One man can clear away $\frac{2}{3}$B in 7/3 hours.
One man can clear away $\frac{1}{3}$B in 7/6 hours.
One man can clear away B in 7/2 or 3 1/2 hours.

Or 3½ men can clear away B in one hour.

As B is the amount that comes down the chute in one hour, 3½ men can keep the dock clear of the coal which falls through the chute. And if 4 men are to clear the dock, only ½ man can clear away A.

From the first condition; 1 man can clear away A and B in six hours. From the solution; 1 man can clear away B in 3½ hours.

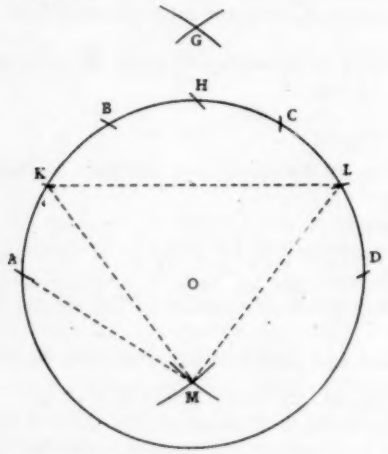
One man can clear away A in 2½ hours. ½ man can clear away A in 5 hours.

Geometry.

507. *Proposed by C. E. Githens, Wheeling, W. Va.*

Given the center and radius of a circle, to find the side of the regular inscribed pentagon by means of the compass alone.

Solution by the Proposer.



Radius = OA = AB = BC = CD.

From points A and D with radius AC describe arcs intersecting at G. From point A describe an arc with radius OG cutting the circumference at H. Arc AH is one fourth of the circumference and, since arc AB is one sixth of the circumference, arc BH is one twelfth of the circumference.

From points A and D measure AK and DL each equal to BH.

From K and L with radius OG describe arcs intersecting at M.

AM = side of regular pentagon.

[The proposer neglected to complete the proof of the construction in the above problem. The editor supplies the following.]

Suppose for simplicity the radius of the circle be taken equal to unity.

$AG = DG = \sqrt{3}$: $AD = 2$: $\therefore OG = \sqrt{2}$. (See also problem 498.)

$KM = LM = \sqrt{2}$: $KL = \sqrt{3}$.

$KA = \sqrt{2-\sqrt{3}}$. (Side of dodecagon.)

$\angle AKL = {}^1/_2\,(210^\circ) = 105^\circ$: $\therefore \angle AKM = 105^\circ - \angle MKL$.

$\text{Cos}\,(MKL) = {}^1/_2\sqrt{3}/\sqrt{2} = {}^1/_4\sqrt{6}$, $\sin\,(MKL) = {}^1/_4\sqrt{10}$.

$\text{Cos}\,(AKM) = \cos\,(105^\circ - MKL) = -{}^1/_4\sqrt{6}\sin 15^\circ + {}^1/_4\sqrt{10}\cos 15^\circ$.

$\overline{AM}^2 = \overline{AK}^2 + \overline{KM}^2 - 2\cdot\overline{AK}\cdot\overline{KM}\cdot\cos\,(AKM)$

$= 2 - \sqrt{3} + 2 - 2\cdot\sqrt{2} - \sqrt{3}\cdot\sqrt{2}\cdot{}^1/_8\,[\sqrt{10(2+\sqrt{3})} - \sqrt{6(2-\sqrt{3})}]$

$= {}^1/_4(10 - 2\sqrt{5})$.

$AM = {}^1/_2\sqrt{10-2\sqrt{5}}$, which we recognize as the formula for the length of a side of the regular pentagon.

508. *Proposed by R. G. Rupp, Hammond, Ind.*

Through a given point P within a given circle draw a chord AB so that the ratio AP:PB shall be equal to a given ratio $m:n$.

I. *Solution by Nelson L. Roray, Metuchen, N. J.*

Let O be the center of the given circle, P the given point and MT the diameter.

Divide MT at S so that MS:ST $= m:n$. Call K the mid point of MS.

With O as center and OK as radius draw circle (2).

With P as center and MK as radius draw circle (3) intersecting (2) at L and Q.

Draw diameter OL (or OQ) intersecting given circle at L'. Then draw chord through L' and P, the required chord.

The proof follows at once by drawing circle with center L and LP as radius.

II. *Solution by Edward Fleischer, Brooklyn, N. Y.*

Let O be the center of the given circle and let CD be the chord perpendicular to OP. Then CP = PD = a (say). Let AP = x and PB = y.

Then $xy = a^2$,

$x/y = m/n$.

Solving, we get $y = \sqrt{a^2 n/m}$.

Therefore y is the mean proportional between a and the fourth proportional to m, a, and n. There will in general be two solutions as a circle with P as a center and y as a radius will in general intersect the given circle in two points. If the ratio m/n ($m < n$) is equal to the ratio of the segments of the diameter through P, there will be only one solution, the diameter. If the given ratio is less than the ratio of the shorter segment of the diameter to the longer, there is no solution.

III. *Solution by Nellie Baughman, Evansville, Ind.*

Let O be the center of the given circle, r = radius.

Construct x, a fourth proportional to n, m, OP.

Construct y, a fourth proportional to n, m, r.

On OP produced lay off PK = x. With center K, radius y, describe arc cutting O at A. APB is the required chord.

Proof:

Draw OB, OA, AK.

OP:PK = $n:m = r:y$ = OA:AK, so AP bisects $\angle$OAK.

$\angle$KAP = $\angle$PAO = $\angle$ABO.

Triangles AKP and BPO are similar.

$\therefore$ AP:PB = KP:PO = $m:n$.

509. *Proposed by R. T. McGregor, Nord, Cal.*

TP and TQ are two tangents, and TRS any chord of a circle. If V is the mid point of RS, and QV meets the circle again in P', prove that PP' is parallel to ST.

I. *Solution by Edward Fleischer, Brooklyn, N. Y., and Nelson L. Roray, Metuchen, N. J.*

Let O be the given circle. Then, since $\angle$OPT, $\angle$OVT, and $\angle$OQT are all right $\angle$s, O, V, P, T, and Q are concyclic. Describe the circle (upon OT as a diameter). Then $\angle$P' = $\angle$TPQ, since each is measured by arc PQ of circle O. $\angle$TVQ = $\angle$TPQ since each is measured by arc QT. Therefore $\angle$P' = $\angle$TVQ and PP' is parallel to ST.

II. *Solution by Nellie F. Henderson, Little Rock, Ark.*

Draw auxiliary lines PR, PS, P'R and P'S, letting PS and P'R intersect at O.

Then $\triangle$sROP and SOP' are similar, since the 3 angles of one equal respectively the 3 angles of the other.

Also, $\triangle$s ROS and POP′ are similar, since an angle of one equals an angle of the other and the including sides are proportional.
$\therefore \angle PSP' = \angle P'RP$ and are $SP' = \text{arc } RP$.
$\therefore P'P$ is parallel to TRS.

Trigonometry.

510. *Proposed by Norman Anning, Chilliwack, B. C.*

If $17\alpha = \pi$, prove $16 \cos\alpha \cos 2\alpha \cos 4\alpha \cos 8\alpha = 1$.

I. *Solution by R. M. Mathews, Riverside, California, Nelson L. Roray, Metuchen, N. J., and Clifford N. Mills, Brookings, S. D.*

$$16 \cos\alpha \cos 2\alpha \cos 4\alpha \cos 8\alpha = 4(2 \cos\alpha \cos 2\alpha)(2 \cos 4\alpha \cos 8\alpha).$$
$$= 4(\cos\alpha + \cos 3\alpha)(\cos 4\alpha + \cos 12\alpha).$$

Expand and multiply in one factor 2.

$$= 2(2 \cos 3\alpha \cos 4\alpha + 2 \cos\alpha \cos 4\alpha + 2 \cos\alpha \cos 12\alpha + 2 \cos 3\alpha \cos 12\alpha)$$
$$= 2(\cos\alpha + \cos 3\alpha + \cos 5\alpha + \cos 7\alpha + \cos 9\alpha + \cos 11\alpha + \cos 13\alpha + \cos 15\alpha)$$
$$= 2 \sum_{p=0}^{p=7} \cos(\alpha + p \cdot 2\alpha) = \frac{2 \cos 8\alpha \sin 8\alpha}{\sin\alpha},$$

by the formula $\sum_{p=0}^{p=p} \cos(\alpha + pZ) = \dfrac{\cos\left(\alpha + \frac{p}{2}Z\right)\sin\left(\frac{p+1}{2}Z\right)}{\sin \frac{1}{2}Z}$

Now

$$\frac{2 \cos 8\alpha \sin 8\alpha}{\sin\alpha} = \frac{\sin 16\alpha}{\sin\alpha} = 1$$

For if $16\alpha = \pi - \alpha$,
$\sin 16\alpha = \sin\alpha$.

II. *Solution by Charles H. Bartlett, student in Hyde Park High School, Chicago, Ill.*

$$16 \cos\alpha \cos 2\alpha \cos 4\alpha \cos 8\alpha = \frac{16 \sin\alpha \cos\alpha \cos 2\alpha \cos 4\alpha \cos 8\alpha}{\sin\alpha}$$
$$= \frac{8 \sin 2\alpha \cos 2\alpha \cos 4\alpha \cos 8\alpha}{\sin\alpha}$$
$$= \frac{4 \sin 4\alpha \cos 4\alpha \cos 8\alpha}{\sin\alpha}$$
$$= \frac{2 \sin 8\alpha \cos 8\alpha}{\sin\alpha}$$
$$= \frac{\sin 16\alpha}{\sin\alpha}$$

But, since $17\alpha = \pi$, $\sin 16\alpha = \sin\alpha$.
Therefore $16 \cos\alpha \cos 2\alpha \cos 4\alpha \cos 8\alpha = 1$.

CREDIT FOR SOLUTIONS.

492. J. A. Bell, Earl G. Baird, Bancroft H. Brown, A. M. Waas, one incomplete and two incorrect solutions. (7)
496. One incorrect solution.
497. Myra J. Howes.
498. R. M. Mathews, one incorrect solution.
500. S. L. Quinby.
502. Florence Pinney, S. L. Quinby.
503. Helen Magner.
505. M. G. Schucker.
506. Earl G. Baird, J. A. Bell, D. E. Davis, Edward Fleischer, C. E. Githens, W. T. Harrow, Frances B. Hatcher, Emor E. Lundin, R. M. Mathews, R. T. McGregor, J. W. Ogg, Florence Pinney, Garson Prenner, S. L. Quinby, M. G. Schucker, H. H. Seidell, Maude E. Smith, J. C. Watkins (2), DeWitt T. Weaver, B. F. Yanney, one incomplete solution, one unsigned solution from Athens, W. Va. (23)
507. C. E. Githens, two incorrect solutions. (3)

508. Nellie Baughman, Edward Fleischer, W. W. Gorsline (2), Felix S. Hales, Murray J. Leventhal, Enor E. Lundin, R. M. Mathews, Florence Pinney, Nelson L. Roray, M. G. Schucker, Raymond E. Staley, DeWitt T. Weaver, one incorrect solution. (14)

509. Emil E. Dreger, Edward Fleischer, W. W. Gorsline, Felix S. Hales, Nellie F. Henderson, Nelson L. Roray, one incorrect solution. (7)

510. Norman Anning, Charles H. Bartlett, Edward Fleischer, Murray J. Leventhal, R. M. Mathews, Clifford N. Mills, Nelson L. Roray (2), G. L. Wagar. (9)

72 solutions.

A Request.

We respectfully request that all contributors read and heed the following rules:

1. Introduce each solution submitted as follows: 999. Solution by (*Your name and address*). It is not necessary to copy the words of the problem. The number is sufficient.
2. Write only on one side of the paper.
3. If two or more short solutions are written on the same page, leave ample space between problems and don't fail to observe Rule 1.
4. Do not make solution dependent on a submitted figure, e.g., do not write "line AB" with no previous verbal definition of A and B, expecting a reader to find the line and points on a figure. It is not always convenient to publish the figure.
5. Where a figure is necessary draw the same accurately and to scale on a separate sheet of paper in jet black or India ink.
6. Introduce each problem proposed as follows: Proposed by (*Your name and address*). When more than one proposed problem is written on a page, leave ample space between problems that they may be clipped.

PROBLEMS FOR SOLUTION.

Algebra.

521. *Proposed by S. L. Quinby, Antioch, Cal.*

Two players sit at solitaire, each with a pack of 52 cards. Each deals himself a hand of four cards. "A" showing his hand remarks, "I have the ace of hearts." "B," doing likewise, replies, "I, also, have an ace." Required, the probability that each of the players holds another ace.

522. *Proposed by Daniel Kreth, Wellman, Ia.*

Solve the equation,

$$x^2+x+\sqrt{x}=22.$$

Geometry.

523. *Proposed by R. T. McGregor, Nord, Cal.*

ABCD is a parallelogram. From any point E on AB a line is drawn parallel to AD meeting DC in F. From any point G on AD a line is drawn parallel to AB meeting BC in H and EF in K. Show that the following lines are concurrent: the joins of A and H, C and E, D and K.

524. *Proposed by N. P. Pandya, Khatri Pole, Bajwada, Baroda, India.*

Two tangents to a circle intersect and then pass through points A and B, respectively, outside the circle. If the points A and B and the length of the chord of contact are known, is it possible to determine the circle?

525. *Proposed by Daniel Kreth, Wellman, Ia.*

Given the distances from the vertices of a triangle ABC to the center of the in circle, to construct the triangle.

LARGE PRODUCTION OF FUEL BRIQUETS.

The production of fuel briquets in the United States in 1916 was 295,155 net tons, valued at $1,445,662, an increase compared with 1915 of 73,618 tons, or thirty-three per cent, in quantity, and $409,946, or forty per cent, in value. The production in 1916 was the greatest recorded, exceeding that of 1914, the previous high record, by 44,520 tons.

SCIENCE QUESTIONS.

Conducted by FRANKLIN T. JONES.
University School, Cleveland, Ohio.

Readers are invited to propose questions for solution—scientific or pedagogical—and to answer questions proposed by others or by themselves. Kindly address all communications to Franklin T. Jones, University School, Cleveland, Ohio.

Please send examination papers on any subject or from any source to the Editor of this department. *He will reciprocate by sending you such collections of questions as may interest you and be at his disposal. Send your first term or mid-year examination papers now.*

Acknowledgment.

The receipt of examination questions is gratefully acknowledged from H. E. Hammond, Kalamazoo, Mich., F. L. Hart, Conway Hall, Carlisle, Pa., Florence Pinney, Sturgeon Bay, Wis., and H. A. Severy, Racine, Wis.

Questions and Problems for Solution.

266. *Proposed by A. H. Smith, Riverside, Cal.*

The nozzle of a fire hose has an opening 2 in. in diameter while the pipe just back of it is 3 in. in diameter. Find the pressure just back of the nozzle when it can throw a jet 60 ft. vertically upward.

267. *Proposed by Robt. W. Boreman, Parkersburg, W. Va.*

In a given calcium solution which would cause the more complete precipitation of Ca, the addition of fluorine ion until its concentration is 0.1 mole per liter, or the addition of the carbonate ion until its conc. is 0.1 mole per liter.

268. *Proposed by C. T. Beach, Tunkhannock, Pa.*

A painter was working on a staging hung by a block and tackle from a painter's hook that rested on a projecting cornice of the building. The rope was, as usual, tied to the staging. On lowering the staging, he passed an iron rod sticking out of the wall, and tied the free end of the rope to the rod. The cornice promptly broke. Why?

269. *Proposed by W. A. Hedrick, Central High School, Washington, D. C.*

What do you think of the questions so often asked by the psychologists to which one and only one answer is possible as in Starch's "Educational Measurements"? They are like this taken from Hall & Bergen, p. 189.

"Supply the omitted word."

Two points so placed with respect to a lens that an object placed at either of them will have an image at the other are called .... of the lens.

This question suggests another. How many readers of this department would like to get together on a set of tests in physics, or chemistry, or other science corresponding to Courtis' "Practice Tests in Arithmetic"? [Write to the Editor of this department at University School.]

BOTANY.

Contributed by Mr. H. A. Severy, Racine High School, Racine, Wis.

First Semester.

Neatness Counts. Answer any ten.

1. a. Discuss the appearance, properties and powers of protoplasm.
   b. Explain the work of protoplasmic or diffusion membrane.
2. a. Discuss root hairs as to (1) origin, (2) form, and (3) function.
   b. Trace and explain the course of the soil water from the time it enters the root hair until it is disposed of by the leaf.
   c. How and why gotten rid of there?
3. a. What is photosynthesis?

b. Discuss the process completely including (1) Materials used, (2) chemical changes involved, (3) function of chloroplasts, chlorophyll and sunlight.

4. Define any 5 of the following: (1) tissue, (2) chromoplast, (3) sieve-tube, (4) tracheid, (5) medullary ray, (6) bud, (7) plumule, (8) cotyledon, (9) endosperm, (10) hypocotyl.

5. Diagram—a. Tangential view of pine block.
   b. Radial view, bringing out the appearance of pits and medullary rays in each.
   c. Explain function of each tissue.

6. a. Draw the 4 principal stages in the germination of the garden bean.
   b. Where is the food material of the seed stored?
   c. When does germination cease?

7. a. Draw a median longitudinal section view of a grain of corn, showing a side view of the embryo.
   b. Label all parts.
   c. Contrast its method of germination with that of the bean, especially as to (1) food storage, (2) position, number and activity of cotyledons, (3) manner of germination process.

8. a. Explain the difference in structure between monocot and dicot herbaceous stems.
   b. How is the structure in each adapted to the mechanical strengthening of the stem.

9. Name the kinds of cells that may be found in xylem and in phloem of monocot and of dicot stems and tell function of each kind.

10. a. Name at least three plants (herbaceous or woody) having the columnar type of stem.
    b. What are some of the advantages of this type of stem habit?

11. Discuss the advantage (at least two) of the cone type of tree over the oval or spreading type, especially in northern latitudes and at higher elevations.

12. Classify buds as to (1) position, (2) content, (3) activity, (4) method of protection, (5) origin of scales.

13. Discuss the three sorts of factors influencing vegetation types.

14. Discuss the vegetation types (meso = xero = and hydrophytes) and the adaptations fitting each type for its habitat.

Solutions and Answers.

229. *Proposed by O. L. Brauer, Selma, Cal.*

To explain the unsymmetrical star of six points, seen when looking obliquely through a wire screen at an arc light.

A further discussion by Loyd C. Elliott, Phoenix, Ariz.

I submit the following as an explanation. The wires form a coarse grating. The light from the arc passing through them is diffracted, which produces a band of light at right angles to the wires. The horizontal wires produce a vertical band and the vertical wires produce a horizontal band. Looking straight through a screen we have a symmetrical cross caused by the two sets of wires at right angles to each other. Thus we see that each set of parallel wires acts as a grating and produces one band of light at right angles to the wires.

As for the six points when viewed obliquely, the principle is the same, the difference is in the construction of the wire screen. One set of wires is straight, the others are woven around these. When looked at obliquely, the wire screen is equivalent to three crossed gratings. Each produces one band of light perpendicular to its wires thus giving a six-pointed star.

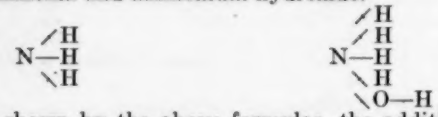
Try the experiment.

231. *Proposed by S. R. Powers, Minneapolis, Minn.*

Is there a change in valence of nitrogen when ammonia gas combines with water to produce ammonium hydroxide? [Explain, using structural formulas showing position of all electropositive and electronegative charges.]

Answer by Dr. W. A. Noyes, University of Illinois, Urbana, Ill.

I would say that the common opinion is that when ammonia combines with water to form ammonium hydroxide, the valence of the nitrogen changes from three to five. This is clear from the following formulas for ammonia and ammonium hydroxide.



As shown by the above formulas, the addition of water to ammonia consists in the addition of hydrogen and hydroxyl (OH) exactly as in the formation of ammonium chloride, NH_4Cl, hydrogen and chlorine add themselves to the ammonia. If you consider in addition to the number of the valences, the sign of the valences, in ammonia nitrogen has three negative valencies, while in ammonium hydroxide or ammonium chloride, it has four negative valencies and one positive valence. The change of valence from three to five does not correspond to the change of valence which takes place in oxidizing or reducing reactions, but this latter point of view has been often overlooked.

244. *Proposed by W. A. Hedrick, Washington, D. C.*

A man weighing 124 lb. has a spring balance weighing 8 lb., a movable pulley weighing 2 lb., a rope whose weight may be neglected and a load of 124 lb. which he wishes to lift.

(a) He arranges the pulley for a minimum pull. He fastens the end of the rope to the *ring* of the balance; and himself pulls on the hook. When the load is just sustained, what will be the reading of the spring balance?

(b) He substitutes himself for the load, and again pulls on the hook of the balance. Is there any difference in the reading of the balance?

(c) He then fastens the original load to himself, and again pulls on the balance, until himself and load are just sustained. What additional pull will the spring balance indicate?

The above question has aroused considerable discussion and a variety of conclusions, due in large part to different interpretations of the question. Types of all the solutions are given.—*Editor.*

Dr. Hedrick explains that he intends using a fixed pulley as well as a movable.

Solution by Florence Pinney, Sturgeon Bay, Wis.

Also solved in this manner by C. T. Beach and W. A. Hedrick.

(*a*) $8+x=\frac{1}{2}(124+2)$. $\therefore x=55$ lb. *Ans.*

Solution by J. P. Drake and F. T. Jones, not assuming an extra pulley.

(a) Force $=\frac{1}{2}(2+124)$. $+8=71$ lb. *Ans.*

[Note carefully these solutions to (b) and (c).—*Editor.*]

By Florence Pinney. (b) $8+x=\frac{1}{2}(124-x+2)$ or $x=38\frac{1}{3}$ lb. *Ans.*, for if he substitutes himself (124 lb.) for the load but at the same time pulls with x pounds on the hook, the reaction will leave a weight of $(124-x)$ pounds on the pulley.

By C. T. Beach.

(b) No.

By W. A. Hedrick.

(b) Suppose the balance is hung on the free end of rope, 16 lb. must be placed on a weightless movable pulley to balance as in (*a*). Hence, if 16 lb. is suspended on the pulley, the spring of an 8 lb. balance will not be stretched at all whether the balance is swung free or attached to the load. In our problem this will leave 3 strings to support 126 lb. − 16 lb. = 110 lb., or the force in each string is $36\frac{2}{3}$ lb. *Ans.*

By J. P. Drake, Emporia, Kansas.

(b) The man's pull is *up*. His reaction is *down*.

F = 8 + 63 + a series of reactions. The summation of this series amounts to 71. $S=\frac{1}{71}\left[\frac{71\times(\frac{1}{2})a-71}{\frac{1}{2}-1}\right]=71$. $\therefore F=71+71=142$ lb.

Proof—The *up* forces = 142 + 124 + 8 + 2 = 276.
The *down* forces = 126 + 8 + 142 = 276.

Also, Mr. Drake writes:

"The proof of the pudding is in the eating. You may be interested to know that I arranged a loose pulley, as shown in the solution that I mailed you recently, and put the strongest man in school on a strap hitched to the pulley and steadied him so that he would not take a double header, being careful not to lift any, and he raised himself a foot the first trial."

In another letter he writes:

"I am enclosing an account of a quantitative experiment on No. 244. The man lifted the 100 lb. weight and himself about a foot and held for 10 sec. This is in accord with the theory, is it not?"

Down forces	wt. of man	190 lb.
	Wt. of pulley and rock	100 lb.
	Reaction	300 lb.
		590 lb.
Up forces	300	
	300	600 lb.
	Error	10 lb.

Per cent error 2 +.

Comment by G. W. Tidd, Emporia.

I would like to know if you consider the problem to have a possible solution. I am skeptical concerning it.

Comment by the Editor.

Does this question differ from asking a man to lift himself by his boot straps? If so, how?

Solution for (c)

Answer by W. A. Hedrick. $124 \div 3 = 41\frac{1}{3}$ lb.

Answer by C. T. Beach. $124 + 124 + 2 = 2(x + 8)$, or $x = 117$ lb. and additional pull is 62 lb.

Answer by Florence Pinney. $8 + x = \frac{1}{2}(124 - x + 124 + 2)$, or $x = 78$ lb. and the additional pull is $39\frac{2}{3}$ lb.

Answer by J. P. Drake.

The reaction here will be $258 \div 2 = 129$ lb.

Force then $= 8 + \frac{1}{2}\ (250 + 133) = 199.5$ lb. and additional pull is 57.5 lb.

250 and 252. *Also solved by Loyd C. Elliott, Phoenix, Ariz.*

CAMPHORS.

When camphor is mentioned, we usually think of a certain pungent and aromatic liquid which is seldom missing from the family medicine shelf. It happens, however, that there are several other camphors and there are cases when we might have to specify just what kind of camphor was meant. For instance, menthol is a kind of camphor made from peppermint (*Mentha piperita*). Thymol is another which is derived from the common wild bergamot (*Monarda fistulosa*). The camphor best known to the public is made from *Laurus camphora*, a plant which is quite closely related to our sassafras and spicewood. Thymol is of more than ordinary interest from the fact that this is the drug depended upon for the cure of unciniariasis or the hookworm disease with which so many residents of the tropics are afflicted. Thymol, however, divides the honors with another plant in eradicating hookworm, for it has been found that oil of chenopodium, made from the seeds of *Chenopodium anthelminticum*, is quite as efficacious in its results.—[*The American Botanist.*

RESEARCH IN PHYSICS.

Conducted by Homer L. Dodge,

State University of Iowa, Representing the American Physical Society.

It is the object of this department to present to teachers of physics the results of recent research. In so far as is possible, the articles and items will be nontehcnical, and it is hoped that they will furnish material which will be of value in the classroom. Suggestions and contributions should be sent to H. L. Dodge, Department of Physics, State University of Iowa, Iowa City, Iowa.

The Modern View of Radiation.

The electrical effects associated with the emission and absorption of light afford a very powerful means of attacking the problem of the nature of radiation and the characteristics of radiating bodies. One of the most important questions that must be answered is whether any disturbance whatever, if of the appropriate type, produces luminosity, or whether the intensity of the disturbance must exceed a limiting value before any light at all is given out. This matter is very much to the front nowadays in connection with the quantum theory, according to which the energy in the light of any wave length is made up of definite units. It should, therefore, be impossible to excite this light with a supply of energy less than one of these units.

Two views are permissible as to the manner in which luminosity is produced. It might, in the first place, be supposed that the vibrator, responsible for the emission, had the characteristics of a violin string which the least disturbance would cause to give off some sound. On the other hand, the vibrator might resemble a bell with a heavy clapper, in which case no sound would be emitted unless the disturbance was strong enough to make the clapper strike the side. If the first analogy holds, the light-giving particle would respond to the smallest possible disturbances; but if the second assumption is the correct one, there would be no emission of light unless the disturbances exceeded some definite limiting value.

Evidence indicating to which of these classes the atoms of luminous bodies belonged was first obtained from the comparative study of flame spectra, arc spectra, and spark spectra. In the flame spectrum of a given element certain lines could be observed but others were absent. In the arc spectrum further lines appeared, while in the spark spectrum lines were observed which were present neither in the flame nor in the arc spectrum. Observations of this nature seemed to show that certain lines required, to bring them out, the supply of a definite amount of energy or at any rate of a disturbance of definite amount.

The conditions in which flame, arc, and spark spectra are developed are, however, not suitable for giving a perfectly definite answer to the problem. Flames, for example, are gases, and, owing to the law by which molecular velocities are distributed, almost every intensity of energy is represented in them. A certain small proportion of the molecules are, in fact, endowed with a very large amount of energy. Matters are still less definite in the case of arc and spark spectra. Consequently, although certain general conclusions can be drawn from a study of such spectra, the conditions are too complicated to permit of any exact determination of the relation between the intensity of the exciting energy and the nature of the radiation produced.

Within the last few years, however, spectra of the simplest possible type have been discovered, each consisting of only one line. The necessary conditions were first realized by Franck and Hertz, who excited

the luminosity by bombarding a rarefied vapor with cathode rays. These rays were produced in enormous quantities from a Wehnelt cathode, which consists of a piece of platinum foil, maintained at red heat, carrying a speck of oxide of barium. Under these conditions the oxide liberates electrons very freely. As soon as an electron leaves the cathode it finds itself in the electric field maintained between the cathode and the anode, and so gains a definite velocity which depends directly upon the potential through which it falls in passing through the tube. Thus, for any given difference of potential between the electrodes each electron will have a definite and determinable velocity and, moreover, the velocity of all the electrons will be the same.

A study of the spectrum obtained from the apparatus when filled with mercury vapor revealed the fact that as long as the potential difference was less than 4.9 volts, the light emitted yielded merely an ill-defined continuous spectrum. So soon, however, as the potential reached 4.9 volts a single bright line made its appearance, having a wave length of 2,536 Angstrom units. This discovery was of profound significance for the energy of each of the negative particles constituting the rays is, at the critical moment at which the line appears, almost exactly equal to that indicated by the quantum theory. According to this theory, the energy required to excite light of a particular wave length is equal to 6.6×10^{-27} times the frequency. If the appropriate computation is made it will be found that 4.9 volts is almost exactly the potential difference through which a negative particle must fall in order to acquire the amount of energy stated above. This result provides, therefore, a remarkable confirmation of the view that definite units of energy are required to produce light of any specified wave length.

Another way of showing, at least qualitatively, the connection between energy supply and luminosity is to place an exhausted bulb, containing a trace of gas, near a coil traversed by a rapidly alternating current. The bulb becomes the secondary of a transformer, and the tendency is for currents to be set up in the gas. If the bulb is placed close to the coil it experiences a strong field, while if it is withdrawn a little the field is weakened. If the bulb is more than a certain distance away, the light given out is diffused throughout the whole tube; but on the critical limit being passed, a brilliant ring of light springs into being inside the bulb. The ring disappears just as abruptly as the distance is again increased, being in all cases either exceedingly bright or entirely absent. The spectrum of the light from such a bulb also changes abruptly with the appearance and disappearance of the ring.

If the experiment is repeated with different gases it is found that the same general effect is produced, but the spectrum and the strength of the field at which the ring appears are different for each gas and characteristic of the gas. It is also found that the absorption of energy changes abruptly with the appearance of the ring, at which time the conductivity of the gas suddenly increases, resulting in a larger current and a corresponding increase in the absorption of energy. Thus these experiments afford further evidence in favor of the view that the emission of certain wave lenghts is made possible only when the intensity of the energy furnishing the excitation exceeds a certain amount.

The examples which have been given furnish conclusive evidence that the conditions under which atoms can be made to give out light are not at all favorable to steady motion. In fact, it is very hard to see how a particle could remain in vibration for any great length of time without suffering interference of some sort. Similar conclusions also follow from considerations of the phenomena of the Zeeman and Stark effects. In the

former the spectrum is altered by the presence of a magnetic field, and in the latter by an electric field. The spectra secured under these circumstances force one to conclude that the light must be produced when the electrons are in a condition of rapid change. Thus all of the evidence which comes from a study of the electrical effects involved in the stimulation of luminosity indicates that the motion of a luminous particle is extremely irregular.

Another point of great importance is the constitution of the energy of the light which is emitted by the luminous particles. Newton regarded light as consisting of a number of small particles moving at great speed. On his theory light was molecular in structure, its molecules being his corpuscles, each of which represented a perfectly definite unit. On the undulatory theory, on the other hand, the energy of light was regarded as a perfectly continuous quantity. This theory has had great success in explaining optical phenomena, in which connection it has long been the only one to be considered. It is very doubtful, however, whether the undulatory theory would ever have been accepted had the electrical phenomena associated with the emission and absorption of light been known. These effects can be accounted for very simply on Newton's view, but are exceedingly difficult to explain on the ordinary conception of the undulatory theory. What is necessary is some way of combining the two so as to get the steadiness of the train needed in optical phenomena, with the individual units of energy required for the electrical effects.

Evidence of the most straightforward kind to the effect that light has some kind of a molecular structure is afforded by the photo-electric effect. If, for example, ultra-violet light is allowed to fall on a plate of metal it causes the metal to shoot out negatively charg d particles with considerable velocity. This velocity can be determined by finding to what positive potential the plate must be charged in order to prevent the escape of the particles. Investigations thus made have shown that the velocity with which the particles shoot out does not depend in the least upon the intensity of the light, but only on its quality.

On the undulatory theory it would be expected that with more light energy falling upon the plate the speed of the particles shot out would be greater. Experiment, however, shows that this speed is the same whether the source of light is close to the plate or far away. So long as there is no change in the quality of light used, the energy in each particle shot out is simply proportional to the frequency of the exciting light and is given by Planck's formula cited above.

Still further evidence in favor of the corpuscular constitution of light is afforded by experiments in which light of certain wave lengths is passed through vapors. Light of an arc is passed through quartz windows into a vessel filled with mercury vapor. If a charged plate placed in the vessel is connected to an electroscope it can be shown that the action of the light is to cause a rapid loss of charge. When, however, a thin piece of glass is interposed in the path of the beam of light the discharge ceases, since it was only the ultra-violet light from the arc which had the property of making the vapor conducting, and this light is stopped by the glass. Accurate measurements show that the effect in the vapor appears quite suddenly with a certain wave length. It cannot be produced by ordinary visible light, no matter how intense. To be effective the wave length of the light must be less than a certain definite value. But with light of this proper wave length the conductivity produced is proportional to the intensity of the light.

This action can be explained readily on Newton's view. To make the gas a conductor a certain energy is required to knock out negative particles from the atoms. "Ultra-violet corpuscles" have sufficient energy to do

this, but "red corpuscles" have not. The fact that there is no effect, whatever the intensity of the light, if it is of too long wave length, is, on the other hand, very difficult to explain on the undulatory theory.

A study of the ionization of gases by X-rays offers additional evidence in favor of Newton's view. These rays are a variety of light, and owing to their very short wave length their effect in rendering gases conductive is very pronounced. Under the action of X-rays the molecules of a gas emit electrons at a high velocity. The number of these negatively charged particles has been shown to be the same, no matter what gas is acted upon, provided in each case the X-rays are all completely absorbed. An electron appears in the gas for every "unit" comprised in the bundle of X-rays. This is exactly the kind of evidence which was thought convincing in proving the existence of "atoms of electricity" in electrolysis, and it is equally forcible in proving the molecular constitution of X-rays.

It is now evident that the modern view of the nature of radiation[1] must harmonize the Newtonian view of a corpuscular radiation with the well-established phenomena which have been so well explained on the undulatory theory. The nature of the mechanism by which light is produced, in so far as it can be known through the sort of experiments that have been described in this and previous articles, is clearly such as would permit of no sustained regularity in the vibration of the ultimate particle producing the light. Evidence of the kind cited in the last few paragraphs forces the conclusion that light itself is not continuous, but is made up of units very similar to the "corpuscles" of Newton. On the other hand, various optical phenomena require a certain regularity in the light. Even though it may not be necessary to regard the light according to the old undulatory theory, these phenomena require the existence of a regular sequence of light units over something more than 100,000 periods. The irregularity with which the light units are produced must be reconciled with the regularity which they are found to possess when studied by means of optical instruments.[2]

According to Sir Joseph Thomson the necessary regularity of phase is imposed on the units by the medium through which they travel. The light unit must consist of some sort of disturbance in the ether, involving changing electric and magnetic fields. There would consequently be a kind of phase relation. Those units whose electric and magnetic fields were in the right direction and of the right magnitude would get through a medium, the others would be sent back till they had learned to arrive in the right phase. When a unit of light came up to an atom disturbed by the passage of a predecessor, it might find the electric field inside the atom opposed to its own field and would consequently fail to get through. Any violent difference in phase would thus give rise to a sorting out of the particles. If exactly in phase they would get through without difficulty, but otherwise they would be expelled, to come back again as the opposing force fell off. They would, as it were, keep knocking and knocking at the atoms of the medium until the conditions were such as to permit of their passage. In this way the medium would impose on the light units a regular sequence of phase. The units could not get through as a disorganized crowd, but must keep in step. On this view the source would keep on erupting units of light irregularly, which would afterward be drilled into step by the surrounding medium.

In this connection it is of considerable historical interest that Newton, in order to explain certain optical phenomena, was led to endow his corpuscles with "fits of easy transmission" and "fits of easy reflection." If

[1] This article is based on the last three lectures of Sir Joseph Thomson at the Royal Institution on "Radiations from Atoms and Electrons."

[2] The optical properties of light were discussed in the December and February numbers.

the corpuseles met the surface of a medium during a fit of easy transmission, they passed through, and in the contrary case were reflected. On the rise of the undulatory theory a good deal of satire was heaped on the arbitrary and artificial character of this conception; but on the electromagnetic theory of light Newton's "fits" form a just corollary to the conception of the way in which radiant energy is transmitted through a medium.

It is found possible, therefore, by suitably combining the undulatory theory and the corpuscular theory of Newton, revised to correspond to modern views and the results of recent experiments, to retain the units, the existence of which is necessary to account for electrical effects, and to obtain the uniformity required in optics.

TO TEST THE FREEZING POINT OF A THERMOMETER.

To test a mercury thermometer at the freezing point, bore a hole down into a block of ice with a half-inch bit, fill the hole with wa'er, insert the thermometer and at the end of five minutes take a reading.

The scheme works well in a large class. Have a block of ice in the sink with a dozen holes bored in it, all filled with water. Temperature is bound to be O, and you are at the same time showing the constant temperature of the interior of the ice.

LAKES OF MORE THAN ONE HUNDRED SQUARE MILES.

The U. S. Geological Survey gives the following interesting list of lakes in the United States, exclusive of the Great Lakes, each more than one hundred square miles in area. The areas of a number of these lakes change materially from time to time, owing principally to variations in rainfall. Tulare Lake, Cal., for example, at times dries up completely. In a lake with shallow water at the margins, such as the Great Salt Lake, the rise or fall of a foot will very materially increase or diminish the water area.

	Square Miles.
Great Salt Lake, Utah (in 1912)	1,800
Lake of the Woods, Minnesota and Canada	1,500
Tulare Lake, California	0 to 800
Lake Okechobee, Florida	730
Lake Pontchartrain, Louisiana	625
Salton Sea, California (January 1, 1909), shrinking	443
Red Lake, Minnesota (both lakes)	441
Lake Champlain, New York and Vermont	436
Lake St. Clair, Michigan and Ontario	410
Rainy Lake, Minnesota and Canada	310
Leech Lake, Minnesota (high water)	234
Leech Lake, Minnesota (low water)	173
Mille Lacs, Minnesota	207
Lake Winnebago, Wisconsin	215
Lake Tahoe, California	193
Flathead Lake, Montana	188
Upper Klamath Lake, Oregon (including swamp area)	156
Upper Klamath Lake, Oregon (excluding swamp area)	87
Utah Lake, Utah	145
Tule Lake, California	144
Lake Pend Oreille, Idaho	124
Lake Winnibigoshish, Minnesota	117
Moosehead Lake, Maine	115

DEPARTMENT OF MATHEMATICS QUESTIONS AND ANSWERS.

Conducted by Herbert E. Cobb,
Lewis Institute, Chicago.

For the many mathematics teachers who are entering the profession every year, and for those who after some years of work and study find themselves at times in doubt concerning questions of subject matter, methods, devices to interest pupils, the history, psychology, or bibliography of mathematics, special problems and the like, this department is established. Probably the question that is perplexing some teacher at the present time has been faced and successfully answered by many others.

It is hoped that many will make use of this opportunity, not only to send in questions, but also to furnish replies to questions already published. Brief discussions, from two hundred to three hundred words, of points brought out in the questions will be appreciated. Address all communications to H. E. Cobb, Lewis Institute, Chicago.

Answers.

5. Has any teacher used graphs at the very beginning of the first year of high school algebra and used them throughout the course? With what success? Any particular difficulty?

Answer by Charles B. Walsh, Ethical Culture School, New York City.

For many years we have used graphic work in our mathematics courses from early in the elementary school throughout the high school. Such work has always been treated as a means, not an end; as illustrative and supplementary, not as a separate topic. It has clarified many difficult notions, such as the function idea. The pupils have enjoyed the work and never found any particular difficulty with it.

We have had the students keep samples of their work in graphs throughout the school in some such notebook and record form as Dr. Weill's *Graphisches Heft*. A suggestion as to our subdivision of the topic by years will be found in the following set of references to M. Auerbach's *An Elementary Course in Graphic Mathematics*, Allyn and Bacon: Seventh school year, pp. 1-5, 8-10, 36-54; eighth, pp. 6-7, 11-15, 19-21, 28-29; ninth, pp. 30-31, 16-18; tenth, pp. 22-24; eleventh, pp. 31-35; and twelfth, pp. 25-27.

6. Too many of my pupils in solid geometry find the first two or three weeks' work difficult and dreary. The proofs are short and not easy to remember, and there are no numerical exercises. What can be done to relieve the situation?

Answer by G. A. Harper, New Trier High School, Kenilworth, Ill.

There are many things that will "relieve the situation." Much interest can be aroused by restating the axioms and theorems of plane geometry to discover how many of them can be used in solid geometry without a limiting statement, and how many of them need the additional words, "in a single plane." It will be noticed that those axioms and theorems whose hypotheses determine a plane are true in solid geometry. For example, "From a point without a line only one perpendicular can be drawn to the line" is true in solid geometry because the given point and line determine a plane. But, "At a given point on a line only one perpendicular can be drawn to the line" is not true in solid geometry because the given point and line do not determine a plane.

The locus idea is an important aid. During this period the pupil proves two or three locus theorems, and other locus ideas and definitions can be introduced if necessary. It will be noticed that the locus of a point satisfying one condition is, as a rule, a surface or a group of surfaces; satisfying two conditions is a line or a group of lines; and satisfying three conditions is a point or a group of points.

Construction work can be made vitally interesting during this period. The pupil should be allowed to assume that he can perform any construction on his figure that is limited to a single plane, provided he learned to do the particular construction in plane geometry. This will allow him to construct a perpendicular from a point without a plane to a line on the plane, but will not permit him to construct a perpendicular to a line at a point on the line unless he defines the plane in which he is working.

I object to the statement that there are no numerical exercises. The diagonal of a room, the distance from a point on the ceiling to a definite point on the floor, the length of the valley rafter of the roof of an L-shaped house, the lengths of guy wires that brace smokestacks, the lengths of projections of line segments that are inclined 30 or 45 degrees to the plane, the lengths of shadows, and the maximum number of lines of intersection of n planes furnish an abundance of material for splendid numerical exercises.

Answer by Charles B. Walsh, Ethical Culture School, New York City.

Memorizing proofs is fortunately always a dreary process. Seriously I suggest making such a performance as much of a bore as possible.

Time will be saved ultimately if demonstrations are postponed for two or three weeks at the beginning of the course in solid geometry. The time could be profitably and pleasantly spent making drawings of solid figures on a plane and reviewing plane geometry, noting where possible the corresponding facts regarding three dimensional geometry. In Betz and Webb's *Solid Geometry*, pp. 327-340, and in other modern texts, there are definite indications of what I mean. Such an introduction will prepare the student to enjoy reasoning his way into the subject.

Answer by Roy W. Lord, Plainfield High School, Plainfield, N. J.

I can heartily endorse the statement that the first few weeks of solid geometry are extremely dreary for everyone concerned when the regular textbook course is followed. I have tried the following scheme for the past three years, and am entirely satisfied with the results.

I start the year with problems on the prism, giving the formulas for lateral area, total area, and volume, without formal proof. I have a fairly complete set of dissected models which are convincing enough, and I assure the pupils that we shall have enough rigorous proofs later in the year to satisfy the most exacting.

I usually complete most of the problems on pyramids by the 1st of November, and then take up the demonstrations in the first book. The pupils are then usually quite ready for the change. I always insist on drawings of the figures represented in the problems, and in that way the pupils acquire ability to visualize the plane representation of the solid figure. I generally give two or three problems a day in connection with the demonstrating work, and can finish the problems on cylinders and cones, and the demonstrations through the parallelepipeds, by midyear. The rest of the work takes care of itself, as it is impracticable to work problems on spheres until the proofs are taken up.

So far as I can see, no phase of the work has suffered, and I think the interest of the pupils is held better than by following the book routine. I do not know of any places that have tried this scheme, and I should be very much interested to learn what success others might have had.

Answer by Zoe Ferguson, Central High School, St. Joseph, Mo.

We begin by taking a thorough review of plane geometry, not proofs, but definitions, theorems, formulas, and corollaries which will be useful in the solid geometry. Then we discuss the fundamental concepts of geometry, the point, line, surface, and solid. I generally take this opportunity to bring in something about geometries of different dimensions in connection with the line, surface, and solid, and then proceed with a brief and informal lecture on the "Fourth Dimension." *Flatland* and *The Fourth Dimension Simply Explained* are good aids for the teacher at this point.

Another good topic for discussion is "The Sources of Authority" which may be used in proving a theorem. (Hilbert's *Foundations of Geometry* is a good aid for the teacher.)

Each proposition which is assigned for home study is thoroughly explained when it is assigned. Sometimes I use pieces of apparatus which the pupils have made for me. For the proposition on the sum of the face angles of the polyhedral angle I use an umbrella!

Right at the start, I ascertain how many members of the class can use logarithms. (Geometry III is a junior subject in our school, and may be taken either before or after Algebra III, where we teach logarithms.) We review the subject thoroughly. Then we use logarithms for nearly all our computation work.

I find that biographies of Napier, Briggs, Riemann, Lobachevsky, and others are very interesting to the students if given in the form of brief, storylike talks by the teacher.

When I come to the regular polyhedrons, we make a sort of a game of it. I introduce at intervals—Mr. Regular Tetrahedron, Mr. Regular Hexahedron (whose "pet name" is Cube), Mr. Regular Octahedron, Mr. Regular Dodecahedron, and Mr. Regular Icosahedron, and we then discuss the *distinguishing features* of each of these new friends, such as Mr. Tetrahedron's *four* equilateral-triangle faces, of which the characteristic features are altitude, $a/2\sqrt{3}$, area, $a^2/4\sqrt{3}$, etc. We also discover that a *hatpin* put in Mr. Tetrahedron's *head*, perpendicular to the base, comes out on the base at a certain particular point each time, viz., at the intersection of the medians or altitudes of the base. We then find that our old friend, the Pythagorean Proposition, again rushes to our assistance in determining the altitude of Mr. Tetrahedron, and that our other old friend, Common Sense, soon assists us in determining lateral area, total area, and volume. Mr. Hexahedron, "Cube" for short, also has those fascinating diagonals, $e\sqrt{2}$ and $e\sqrt{3}$, as well as numerous other interesting features.

How could anything so charming as the subject of loci be dreary and uninteresting? Imagine trying to find the locus of points equidistant from four points not all in the same plane, and when you have worked it all out with pieces of stick and marks on the floor to find that you have discovered something new and entirely different, namely, that wonder and delight, the Perfect Sphere!

Questions.

4. (Corrected). Is there any proof for the methods given in mechanical drawing for the construction of regular polygons of seven, nine, eleven, and so on, sides?

8. How would you show that the sum of the dihedral angles of any trihedral angle is greater than two right angles?

9. Can factoring be made real and understandable by the use of graphs? Who has tried it?

10. Explain the difference between an angular degree and a circular degree.

SWEET GUM.

Everybody in the Gulf States and for some distance north and east of that region knows the sweet gum (*Liquidambar styraciflua*), whether they call it by this name or know it as bilsted, star-leaved gum, or alligator tree. It is not likely, however, that many of them realize that this tree is a close relative of the witch-hazel (*Hamamelis Virginiana*), but both belong to the Hamamelidaceae. Of recent years, the sweet gum has become of much commercial importance, and under the name of red gum is now used for furniture, interior finish, and the like, running a close second to oak in this respect. It is estimated that one-eighth of all the hard-wood still standing in the United States is red gum. Though this tree grows naturally as far north as Connecticut and southern Illinois, it thrives under cultivation much farther from the equator. The brilliant coloring of the leaves in autumn, together with their unusual shape, makes the trees most desirable specimens for street planting, while the curious prickly globes of fruit and the corky winged branches add to their attractions. From wounds in the trunk a clear gum oozes out which is much used as chewing gum in the region where it grows. A single other species is found in Asia Minor.—[*The American Botanist.*

BIOLOGY AT AN INLAND BIOLOGICAL STATION.

Teachers of biology in inland schools will be glad to learn of the possibilities of studying plants or animals, or of doing investigation work along biological lines at a fresh water biological station which has passed beyond the experimental stage, and where opportunity is given to study living organisms both in the field and in the laboratory. For the past eight seasons the University of Michigan has maintained a biological station at Douglas Lake in Cheboygan County, Michigan, as a part of its regular summer session. At this station regular courses and investigational work in the natural history and ecology of plants and animals of fields and forests, streams and lakes, are carried on under the direction of specialists chosen from the teaching staff of the University of Michigan and from other universities. The courses are directly of value to the teacher who wants to learn more of animals in their natural environment, and these courses are designed to supplement rather than to duplicate those given in the usual curriculum of colleges and universities.

Living conditions are excellent but somewhat unusual. All members of the station live in storm-proof tents in a well-organized camp, and they take their meals at the common mess which is conducted on the co-operative plan. Swimming and boating after working hours and gathering about bonfires on the beach furnish the chief forms of recreation for the members of the station. The health of the members is cared for by the station physician, who also sees that the camp is kept in a sanitary condition.

While the work of the various classes is done largely in the field or on the water, proper laboratory facilities are at hand for use when necessary.

The climate of northern Michigan is invigorating. A large proportion of the days are clear. There is usually but a small per cent of hot days. but even in hot weather the nights are always cool. Students who arrive jaded and the worse for wear from a year's work in the classroom almost without exception leave at the close of the session in excellent condition to resume their studies. Not the least of these advantages is the moderate expense attached to a summer spent in study at this station.

Inquiries should be addressed to: Director, the Biological Station, Ann Arbor, Michigan.

ARTICLES IN CURRENT PERIODICALS.

American Forestry, for March; *Washington, D. C.; $3.00 per year, 25 cents a copy:* "Recreational Uses of the National Forests," Henry S. Graves, eight illustrations; "Conservation of Game in the National Forests and National Parks," E. W. Nelson, ten illustrations; "Sycamore or Buttonwood Tree Flower," Dr. R. W. Shufeldt, one illustration; "Save Us from Invading Pests," J. G. Sanders, nineteen illustrations; "Birds and the Camera," A. A. Allen, six illustrations; "The Slash Pine," Wilbur R. Mattoon, seven illustrations; "Early Spring and Summer Flowers," Dr. R. W. Shufeldt, seven illustrations.

American Journal of Botany, for March; *Brooklyn Botanic Garden, N. Y.; $5.00 per year, 60 cents a copy:* "Matroclinic Inheritance in Mutation Crosses of Oenothera Reynoldsii," Carl D. La Rue and H. H. Bartlett; "Duration of Leaves in Evergreens," Vinnie A. Pease; "The Relation Between Evaporation and Plant Succession in a Given Area," Frank C. Gates.

American Mathematical Monthly, for March; *5548 Kenwood Ave., Chicago; $3.00 per year:* "Directed Angles in Elementary Geometry," R. A. Johnson; "Mathematics in the New International Encyclopedia," G. A. Miller; "New Rule for Quadrature," P. J. Daniell; Some Metrical Properties of the Pentahedroid in a Space of Four Dimensions," M. H. Szynter.

Geographical Review, for March; *New York City; $4.00 per year, 40 cents a copy:* "Tribal Distribution and Settlements of the Fuegians, Comprising Nomenclature, Etymology, Philology, and Populations," Charles W. Furlong, (3 maps, 4 photos); "The Geographical Work of Dr. M. A. Veeder" (first half), Ellsworth Huntington, (1 diagr., 1 photo); "Askja, a Volcano in the Interior of Iceland," W. S. C. Russell, (1 map, 5 photos); "New England Snowfall," Charles F. Brooks, (20 maps).

Journal of Educational Psychology, for February; *Baltimore, Md.; $3.00 per year, 35 cents a copy:* "A Study of the Memory of Young Women," Cephas Guillet; "Practice and Transference in Normal and Feeble-Minded Children. Part I: Practice," Herbert Woodrow; "An Investigation into the Rate of Mental Association," Minnie Anderson; "Problems of Teacher Measurement," B. F. Pittinger.

Journal of Geography, for April; *Madison, Wis.; $1.00 per year, 15 cents a copy:* "The Weather Factor in the Great War, VI," R. De C. Ward; "Ship-building in the United States, Past and Present," L. B. Krueger; "The Resources of California," M. G. Edwards; "Mathematical Geography in the Grades," C. G. Stratton; "Crossing the 180th Meridian," H. E. Gregory; "A Laboratory Exercise on the Mercator's Projection Map," Louise W. Mears; "A Lesson in Map-reading in the Fourth Grade," Ruth Batchelder; "Report on Commercial Geography," J. Paul Goode.

Literary Digest, for March 31; *New York City;* "Democratic Russia as Our Ally;" "Japan in Our Break with Germany;" "Swatting the Submarine;" "'Scientific Management' in Arithmetic;" "Watering Plants Drop by Drop;" "Bucking Record Drifts."

Nature-Study Review, for March; *Ithaca, N. Y.; $1.00 per year, 15 cents a copy:* "The White Rat as a Pet," H. D. Bailey; "Nature-Study and Humaneness," Guy A. Bailey; "De Sachet, a Pet Skunk," Harry H. Knight; "A Reading of the Nature-Study Barometer," Louise Connolly; "A Pet Pine Snake," Karl P. Schmidt; "The Goat—An Appreciation," W. P. Alexander; "Fishing in Winter," Mathilde Schlegel; "Animal Folks in the Meadow," Jane Bielby.

Physical Review, for March; *Ithaca, N. Y.; $6.00 per year, 60 cents a copy:* "On the Free Vibrations of a Lecher System, IV," F. C. Blake and Charles Sheard; "The Comparison of a Certain Case of the Elastic Curve with its Approximation," R. W. Burgess; "The Effect of Previous Filtering upon the Absorption Coefficients of High Frequency X-Rays," S. J. Allen and L. M. Alexander; "A Calorimetric Resistance Thermometer," S. LeRoy Brown; "Photoelectric Potentials for Extremely Short Wave-Lengths," P. E. Sabine; "X-Ray Emissivity as a Function of Cathode Potential," David L. Webster; "An Attempt to Detect a

Change in the Emissive Properties of Platinum and of Tungsten at Incandescence with a Change in the Method of Heating," A. G. Worthing; "Spontaneous Generation of Heat in Recently Hardened Steel, II," Charles F. Brush; "The Measurable Quantities of Physics," Richard C. Tolman.

Popular Astronomy, for April; *Northfield, Minn.; $3.50 per year:* "Percival Lowell, with Plate IX;" "Twentieth Meeting of the American Astronomical Society;" "The Nature of Matter," J. C. Whitehorn; "Learning the First-Magnitude Stars," Frederic C. Campbell; "Some Southern Double Stars," Bernard Thomas; "Vega Lyrae," Charles Nevers Holmes; "The Meteor of February 5, 1917," Edwin B. Frost; "The Sunspot of February 9, 1917, Plate X."

School World, for March; *Macmillan and Company, London, Eng.; 7s 6d per year:* "The Care of the Eyes of School Children, I," N. Bishop Harman; "Girls' Schools in the New Era," Sara A. Burstall; "The Objects of Science Teaching in Schools," Rev. J. R. Wynne Edwards; "The Education of Girls and the Position of Women Teachers in Scotland," Ainslie; "Research in Education," William Boyd; "The Natural Sciences in Public Schools."

SCIENCE AND MATHEMATICS DIVISION OF OREGON TEACHERS ASSOCIATION.

The Science and Mathematics Division of the Oregon Teachers' Association met in annual session on the 28th and 29th of December, in Lincoln High School, Portland, Ore. The programs were centered in the discussion of three main topics, "Mathematics," "General Science," and "Physics." This plan was followed at the request of the Executive Committee, and to concentrate attention on a fewer topics. This plan proved successful, if the attendance and interest in the discussions are criterions of success.

The regular program included the following addresses and papers: "The Mathematical Responsibility of the High School," by Prof. Frank L. Griffin, of Reed College; "Mathematical Deficiencies of Students Entering College," by Dr. R. M. Winger of the University of Oregon; "The Why of General Science," by Prof. L. P. Gilmore of the Oregon Normal School; "The How of General Science," by Francis D. Curtis of the James John High School, Portland, Ore.; "The Project Method of Teaching Physics," by Dr. G. W. Wilder of the Benson Polytechnic School, Portland; "Some Aspects of the Problem Method," by Supt. George Schantin of Sutherlin, Ore. All of the papers merit attention, and deal with some of the more pertinent questions of science teachers. These papers will be published in early numbers of the *Oregon Teachers' Monthly*.

Two special committees were appointed to investigate respectively these two questions—(1) the better correlation of high school courses in mathematics, and (2) the content and method of high school courses in science with particular reference to the smaller high schools. The reports of these committees will be made the subject of discussion at one of the sessions of the next meeting.

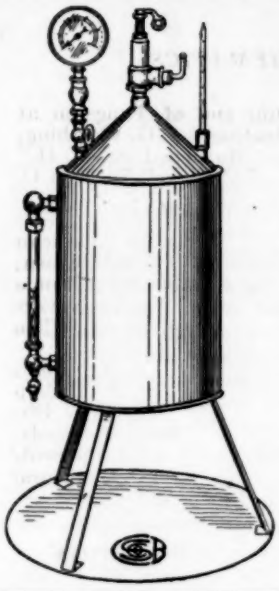
The officers of the Science and Mathematics Association are:

President—Professor L. P. Gilmore, Oregon State Normal School.

Secretary-Treasurer—E. L. Keezel, Extension Division, University of Oregon.

Executive Committee—L. P. Gilmore, Chairman; E. L. Keezel, Secretary; Prof. A. F. Bittner, Jefferson High School, Portland, Ore.; Francis D. Curtis, James John High School, Portland, Ore.; J. L. Whitman, Pendleton High School, Pendleton, Ore.

E. L. KEEZEL,
Secretary.



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BURNING COAL BEDS FORM NATURAL BRICK.

Many coal beds in the great coal fields of the Western States have at some time taken fire and burned along their outcrops, baking and reddening the overlying strata so that they have become a kind of natural brick or terra cotta. The fires were in places hot enough to fuse and recrystallize the overlying shale and sandstone so as to form natural slag. At some places this slag resembles true igneous rock; at others it consists largely of rare minerals. Thoroughly fused slag seems to occur chiefly in crevices or chimneys through which the hot gases generated in the burning escaped through the overlying strata to the surface. The chimney-shaped masses of slag are harder than the surrounding baked rock and, after that has weathered away, form the curious pinnacles that surmount many clinker bluffs or buttes in the West.

Some of the coal beds, especially those exposed on the higher hills, were perhaps ignited by lightning; others, according to well-authenticated reports, were ignited by prairie fires or camp fires; but as burning on the outcrop has been so common as to affect most of the coal beds in an area of more than two hundred thousand square miles, much of it has probably been due to spontaneous combustion.

Coal beds are now burning at or near the surface at many places in the West, where the burning of the bed is disclosed by the smoke and fumes that rise from it and by the heat at the surface of the earth near the outcrop or above the bed—heat so intense that it kills all vegetation. As the coal burns out the overlying rock or earth generally caves in so as to form large fissures in the ground. As the burning works back, from the outcrop, the heat acts on the overlying rocks, but finally combustion is smothered for the lack of oxygen. It is difficult to say how far back from the outcrop the burning may extend. Field studies made by the United States Geological Survey, Department of the Interior, indicate that a bed lying beneath twenty feet or less of cover may burn out completely under large areas, and even where the cover is several hundred feet thick the burning may extend five hundred feet back from the outcrop.

PHOTOMETRY OF THE GAS-FILLED LAMP.

The new high efficiency gas-filled lamp introduces variables not hitherto encountered in the photometry of incandescent electric lamps. This matter has been made the subject of a study by the Bureau of Standards, Department of Commerce, and the results thereof have just been published in *Scientific Paper, No.* 264.

On account of the comparative broadness of the filament spiral and the dissymmetry of the filament mounting, there is considerable irregularity in the distribution of the light about the vertical axis. Consequently, when the lamp is rotated, as is commonly done in rating lamps at the factory, the light as seen in the photometer flickers so excessively as to render accurate measurements of candle power practically impossible without the use of auxiliary apparatus. However, as is sometimes done, if two mirrors inclined to each other be placed back of the lamp, the flickering is so much reduced as to permit accurate candle power measurements even at very low speeds of rotation.

But this expedient does not eliminate the most serious trouble caused by rotation. It was found that at constant voltage both the current consumed and the candle power are different when the lamp is rotating than when it is stationary, the current changing in one direction and the candle power always in the opposite direction; that is, there is a change in the operating efficiency of the lamp. Furthermore, this change in efficiency may be either positive or negative, depending upon the speed, and it is about twice as great when the lamp is rotating tip up as when it is tip down.

Fortunately, from the standpoint of photometry, there is for each lamp in either position a particular speed at which the current and the candle power have the same values, respectively, as when the lamp is stationary. Hence, with the lamp rotating at this speed, its candle power can be measured with accuracy in spite of its rotation. The speed for the above condition is practically the same for all lamps having the same number of loops in the filament; but, for lamps having different forms of filament mounting, it varies from lamp to lamp, being greatest for those having the smallest number of loops in the filament.

If the above precaution as to speed adjustment is not observed, and lamps are rated while rotating at speeds ordinarily used in photometering vacuum lamps, the errors which enter may amount to as much as one to two per cent in current, or watts, in one direction, and as much as fifteen to twenty per cent in candle power in the opposite direction. Hence, the voltage found for a desired operating efficiency may be so much in error as to give a lamp on test at this rated voltage a fictitious life value three or four times as large as the lamp would give if it were operated stationary at a voltage corresponding to that efficiency which during the rating was only apparent. That is, the lamp may be given credit for a much longer life than it really deserves. On the other hand, the speed may be such as to cause errors in the opposite direction, resulting in a lamp life much shorter than would be expected from the apparent efficiency rating.

Another peculiarity of the gas-filled lamp is that while it burns the blackening occurs, not all over the bulb in approximate proportion to the light distribution as in the vacuum lamp, but principally at the top of the bulb, because the volatilized material is carried upward by the gas. Hence, in making a life test, a true measure of the reduction in total light during the life of the lamp cannot be obtained, in the usual manner, by mean horizontal candle power measurements, but by determinations of the total flux or mean spherical candle power. This is accomplished most rapidly and conveniently by means of an integrating photometer, such as the Ulbricht sphere, in which the lamp is measured stationary, and thus all

"When good luck comes to thee, take it in," said Sancho Panza to his master. Much the same advice applies in the case of

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the complications arising from rotation are entirely avoided.

As to the cause of the variations observed in candle power and efficiency when the lamp is rotated, it is concluded from the result of a number of special tests that the whole effect is produced by a change in the convection currents of the gas, a consequent variation in the temperature distribution in the bulb, resulting in a change in the resistance, and therefore a variation in the current and candle power of the lamp.

GERMINATION OF ACORNS.

It is well known that the seeds of many plants will not grow as soon as ripe, but require a certain period of rest before growth is resumed. In consequence of this, it is customary for foresters and nurserymen to stratify the seeds of trees and shrubs in moist sand and bury them in the soil over winter. It now appears, however, that the need of a rest period for some seeds is not as important as has been assumed. A number of specimens are known whose seeds under proper conditions will grow as soon as ripe, and, in the case of the tomato, seeds taken from green fruits have been known to sprout. Beans will often sprout in the pod if the late summer happens to be moist. Probably the most celebrated instance of seeds sprouting while yet attached to the plant is afforded by the mangrove (*Rhizophora mangle*) in which the seeds develop into young plants of considerable size before separating from the parent plant. This phenomenon has been found, though in a lesser degree, in some of our oaks. In the red oak it is found that the young plant after filling the seed continues to develop while still attached to the tree. Dr. John H. Harshberger has investigated other oaks and finds that the acorns of the white and black jack oaks will grow as soon as ripe if the shells are not allowed to become dry. That the seeds of the white and red oaks will grow the same season they are produced has long been known. Under favorable conditions one is likely to find, late in fall, that the acorns have already pushed down good-sized roots, though no sign of a shoot will be visible until spring. —[*The American Botanist.*

NEW YORK STATE SCIENCE TEACHERS ASSOCIATION MEETING AT SYRACUSE, N. Y., DECEMBER 29-31, 1916.

The meeting was called to order by the President, E. F. Conway.

The Secretary-Treasurer was called upon for a report which was as follows:

The Auditing Committee nominated for the past year passed upon the Treasurer's account under date of April 5, 1916. The Treasurer's books at that date showed total receipts of $202.98, a total expense of $164.32, leaving a balance of cash on hand of $38.66.

The total registration for the meeting, December 28 and 29, in Syracuse, is forty-three, and of these twenty-seven are Class A members.

The Secretary recommended that he be permitted to withhold the final balancing of his account for approval by the auditors until later when the incoming dues will be more nearly complete.

The Treasurer's report as read was ordered accepted.

The President then called for the report of the committees.

The auditors, Mr. George W. Fowler, of Syracuse, N. Y., and Miss Lucy Latham, of Kenwood, N. Y., stated that their reports would be deferred until later.

The Committee on Resolutions, of which Mr. Collister was Chairman, with Mr. Barbur and Mr. Currier as associatess, read the following resolution which was thereafter adopted by the Association:

"The New York State Science Teachers' Association, assembled at Syracuse, N. Y., for the purpose of our annual meeting, have hereby

"Resolved, That we express our appreciation to the Board of Education for their kindness in opening their Central High School to us for these meetings.

"Resolved, That we extend a vote of thanks to the various speakers who have helped to make this meeting one of both pleasure and profit.

"Resolved, That we express our appreciation to Mr. Nixon of the Bausch and Lomb Optical Co. for furnishing and operating the projection lantern used for our lectures.

"Resolved, That we also extend our thanks to the L. C. Smith Typewriter Co. both for the privilege of visiting their plant and for the many courtesies shown us by the conductors of our party.

"Resolved, That we acknowledge our indebtedness to the Press of the city, especially the *Post Standard*, for its helpful cooperation."

The Committee on Nominations, consisting of Mr. Porter, Chairman, Mr. Carey, and Mr. Abbey, nominated as follows:

For President, Mr. R. C. Gibbs, Cornell University, Ithaca, N. Y.

For Vice-President, Mr. Harry A. Carpenter, West High School, Rochester, N. Y.

For members of the council, to serve until 1920, Mr. D. H. Childs, Buffalo, N. Y., Mr. M. C. Collister, Utica High School, Utica, N. Y., and Mr. E. F. Conway, Central High School, Syracuse, N. Y.

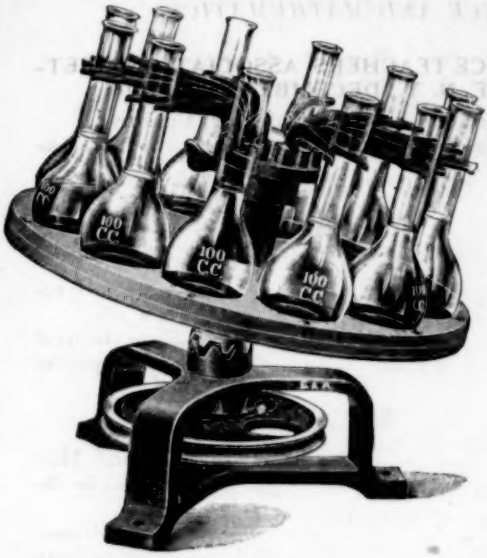
Motion was made and carried that the report of the Nominating Committee be accepted and that the Secretary cast one ballot for the election of those nominated. The Secretary cast the ballot, and the members as nominated were declared duly elected.

The following resolution was introduced and discussed by Prof. R. C. Gibbs:

"Whereas, Many teachers in the secondary schools of this state are often required to teach subjects in which they have had no special preparation, be it

"Resolved, That the New York State Science Teachers' Association request the Commissioner of Education of this state to consider the advisability of issuing differential licenses, i. e., licenses by subjects, to teachers in the secondary schools of New York State."

After discussion by other members, the resolution was adopted by the Association and the Secretary was instructed to send a copy of the resolution to Dr. Finley of the State Department.



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REPORT OF THE BUSINESS MEETING OF THE PHYSICS AND CHEMISTRY SECTION.

The meeting was called to order by the Chairman, Prof. Waldo A. Titsworth. The Chairman called for reports of the Committee on Nominations, which presented the name of Mr. M. C. Collister, Utica High School, Utica, N. Y., for Chairman of the section.

The report was accepted and the Secretary cast one ballot for the election of Mr. Collister as nominated.

The President thereupon declared him duly elected.

BIOLOGY SECTION.

The Biology Section of the Science Teachers Association of New York State assembled at Central High School, Syracuse, N. Y., Friday, December 29, 1916.

Miss Caroline Riker of Canandaigua, N. Y., as Chairman of the section, opened the day's session by appointing Miss Ida Revelry, Mr. H. M. Eaton, and Miss Margaret Reidy a committee to nominate the Chairman for the Biology Section for 1917.

Mrs. Anna B. Comstock, of the Department of Entomology, of Cornell University, was then introduced, who gave a most interesting and practical address on "Nature Study Methods, a Help in Teaching High School Biology." She showed a thorough appreciation of one of the great problems of the biology teacher, namely, the teaching of nature study along with the more scientific aspects of the subject. She spoke of the gradual loss of initiative among the children, expressing it as "the putting up of mental umbrellas." In a most charming manner she showed by practical application how several lessons might be developed, by means of which the interest of the child could be held and the scientific fact thoroughly taught as well—thus successfully combining nature study with the real science of biology and present-day problems. Mrs. Comstock's address was very practical as well as most inspirational.

This paper was followed by Mr. H. M. Eaton, of Schoghticike, N. Y., who discussed "Laboratory Problems." Mr. Eaton spoke of the problems confronting the biology teacher of the small high school. He spoke of the many trying experiences of the biology teacher, such as the lack of preparation of the student, lack of initiative among pupils, poor equipment, and lack of room for adequate work, and offered several practical suggestions to remedy or alleviate these troubles.

After Mr. Eaton's paper the section adjourned to inspect rate books and biological apparatus on exhibition in an adjoining laboratory, and for the noon luncheon.

At 2 p. m. the section reassembled, and Miss Ida M. Revelry, as Chairman of the Nominating Committee, reported the nomination of Dr. George Hargitt for Chairman of the Biology Section for 1917. Mr. Clements moved that Dr. Hargitt be elected; the motion was seconded and carried unanimously.

Miss Margaret M. Reidy, of Ithaca, N. Y., then read a paper on "Ecology," in which she mentioned many interesting and striking features of the adaptations of the animals of our own locality.

Mr. E. H. Eaton, Professor of Biology of William Smith College, Geneva, N. Y., who was to give a paper on "The Value of Bird Study in Secondary Schools," was unable to be present, so Miss Reidy's paper was followed by a round table conference with question box, led by Mr. A. G. Clement. Several essential questions were submitted which provoked an interesting discussion.

After the question box Miss Sadler and Miss Hamson, of Central High School, very cordially invited the section to their laboratory, where tea was served and a very pleasant half hour enjoyed.

The session closed with a delightful steropticon lecture given by Miss Thomas of the Department of Education of the Natural History Museum of New York City. Miss Thomas showed the broad educational work which that institution is promoting among the children of Greater New York.

COUNCIL MEETING, THURSDAY, DECEMBER 28, 1916, 5 P. M.

Mr. Conway in the Chair.

Present: Mr. Gibbs, Mr. Cobb, Mr. Cady, Mr. Carpenter.

The business presented to the members of the council was concerned with meetings for the year. It was suggested and favorably considered that section meetings be held at various points in the state under the auspices of the Association; that these meetings come at such time as not to interfere with other science meetings; and that they be for the purpose of bringing together locally the teachers of science and for the purpose of interesting as many as possible of the local teachers in assisting more actively in the work of the Association.

Plans were also considered regarding the next regular meeting of the Association. It having been determined that the State Teachers' Association is to be held in Syracuse in November, 1917, it was suggested and favorably considered that some plan be devised whereby the New York State Science Teachers' Association should meet in conjunction with the Science Section of New York State Teachers' Association; further plans to be left with the President and Executive Committee.

COUNCIL MEETING, DECEMBER 29, 1916.

The meeting was called to order by the President, and the Secretary was asked to read a resolution handed to him dealing with Section 28 of Chapter 566 of the Laws of New York State, passed on May 15, 1916, known as the Slater Bill. It had been requested that this resolution be read before the Association for consideration. The council considered the resolution and, inasmuch as the business meeting of the Association of the year had passed, decided that the matter should be laid upon the table.

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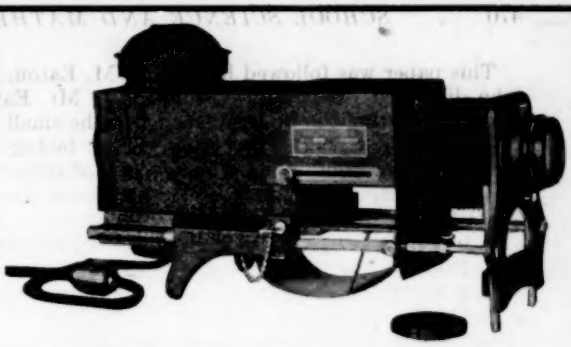

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Receipts.

Balance on hand		$ 38.66
1	1915 Class B dues	1.00
5	1916 Class B dues	5.00
26	1917 Class B dues	26.00
3	1916 Class A dues	6.00
54	1917 Class A dues	108.00
Exchange on checks		1.40
6 pages advertising at $5.00		30.00
Total		$216.06

Expenses.

3	1916 subscriptions to SCHOOL SCIENCE AND MATHEMATICS	$ 4.50
54	1917 subscriptions to SCHOOL SCIENCE AND MATHEMATICS	81.00
Dec. 8, 1916,	printing bill cards, Wm. H. Leahy	4.50
Dec. 13, 1916,	stamped envelopes for mailing programs	21.24
Dec. 19, 1916,	clerk help, mailing, etc.	6.00
Dec. 28, 1916,	President's expenses, E. F. Conway	9.37
Jan. 8, 1917,	Biology Chairman, expenses, C. A. Riker	6.85
Jan. 10, 1917,	Secretary-Treasurer's expenses, H. A. Carpenter	7.12
Jan. 10, 1917,	printing programs, E. M. Eddy	20.00
Jan. 10, 1917,	printing poster cards for Syracuse meeting	2.70
Feb. 8, 1917,	printing 1915 programs, Academic Prin. treas.	5.21
Feb. 14, 1917,	speaker's expenses, C. H. Milligan	5.90
Feb. 14, 1917,	Physics and Chemistry Chairman, expenses	4.62
Mar. 12, 1917,	Secretary-Treasurer, expenses, mailing, and clerk	2.30
		$181.31
March 27, 1917,	balance on hand	34.75
		$216.06

HARRY A. CARPENTER, *Secretary-Treasurer.*

USEFUL MINERALS OF THE UNITED STATES.

A new edition of the popular work, entitled: *Useful Minerals of the United States*, is being published by the United States Geological Survey, Department of the Interior, as Bulletin 624. It is a revised, enlarged, and up-to-date edition of a bulletin that was issued about two years ago. A large edition of that bulletin was published, but it soon became exhausted, and several thousand applications for it were received after the edition printed had been distributed.

Bulletin 624 notes the enormous increase in development, production, and value of the useful minerals of the country during the last twenty-five years, and many of the changes and discoveries that have taken place in the mineral industry. It aims also to supply the rapidly growing demand for information regarding our mineral resources and the special demand occasioned by the European war.

Besides giving several thousand new localities of mineral deposits and adding more than 160 new mineral names to the glossary, the new bulletin furnishes considerable additional information concerning certain minerals, especially the uranium and vanadium minerals found in the high plateau region of the West. The present bulletin, like the earlier work, gives concisely, by states and counties, the location of the principal deposits of useful minerals and includes a glossary showing the composition and character of each mineral and the location of its principal deposits. It gives also the principal uses of each mineral, which were not stated in the first edition. As a mineral directory it promises to be of service to scientific bureaus and educational institutions that prepare replies to the numerous inquiries of the general public on subjects connected with what may be called commercial mineralogy, as well as to the prospector, miner, manufacturer, and business man, and the student of economic conditions.

BOOKS RECEIVED.

Guide to the Insects of Connecticut, by Wilton E. Britton, State Entomologist. 824 pages. Ten plates. 14x23 cm. Paper. 1916. $2.00. State Librarian, Hartford, Conn.

Introduction to Inorganic Chemistry, by Alexander Smith, Head of the Department of Chemistry, Columbia University. Third edition. Pages xiv+925. 13.5x20.5 cm. Cloth. 1917. The Century Company, New York.

Centrifugal Pumps, by R. L. Daugherty, Sibley College, Cornell University. Pages ix+192. 16x23.5 cm. Cloth. 1915. McGraw-Hill Book Company, New York City.

BOOK REVIEWS.

Handbook of Engineering Mathematics, by Walter E. Wynee and William Spraragen. Pages x+220. 10.5x17.5 cm. Leather. 1916. $2.00. D. Van Nostrand Company, New York City.

This is an especially strong little handbook which has been prepared by men who are vitally interested in engineering mathematics. It is intended perhaps primarily for students in engineering schools. It is a convenient reminder of those expressions, tables, and formulas which the practicing engineer meets in his everyday work. The book is of a convenient size to carry in one's pocket. It is splendidly printed, and the composition could not be better. It would be well for all students of engineering to own a copy. C. H. S.

Practical Drawing, by Harry W. Temple, Crane Technical High School, Chicago. 141 pages. 24.5x19.5 cm. Cloth. 1917. D. C. Heath & Company, Boston, Mass.

This is a book which couples eighth grade work with that of the high

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school, and it is written primarily to give pupils in the high and technical schools ability in the reading and construction of working drawings. It is printed on greenish paper, with two columns on each page. The descriptive matter is given on the left-hand page, and the drawings appear in the main on the right-hand page. The drawings are exceedingly well rendered. It is a book that any instructor in mechanical drawing can well use in his classes. C. H. S.

Household Accounting and Economics, by William A. Shaeffer, West Division High School, Milwaukee, Wis. Pages xi+161. 13x19.5 cm. Cloth. 1917. $0.65. The Macmillan Company, New York City.

How few housewives realize that the management of a home is a business proposition! The people who preside over the homes of our country should operate that phase of the home which has to deal with the expenditure of money on a business basis. If this were done, home keepers would have larger bank accounts, and there would be less domestic infelicity and less cause of complaint of the high cost of living. This little book will teach housekeepers how to keep house in the most economical way. It is a volume with a mission, and it should be in every home in the country. C. H. S.

Centrifugal Pumps, by R. L. Daugherty, Sibley College, Cornell University. Pages ix+192. Cloth. 1915. The McGraw-Hill Book Company, New York City.

This splendid book has an important mission to perform in hydraulic engineering. The recent rapid developments in raising water and sewage by means of centrifugal pumps is causing hydraulic engineers to be masters of literature on the subject if they wish to be abreast of the times. This is a splendid book, written by a past master in the subject. It contains sixteen chapters and presents the theoretical as well as the practical side of centrifugal pumping. There are 111 cuts and half-tones scattered throughout the book, which have been selected with the greatest care and vividly illustrate the points in the text. There are many problems given at the end of each chapter. There is an appendix of 105 problems. Many tables are given. The index is complete. C. H. S.

Elements of Analytic Geometry, by Alexander Ziwet, Professor of Mathematics, and Louis A. Hopkins, Instructor in Mathematics, The University of Michigan. Pages vii+280. 13x19 cm. 1916. The Macmillan Company, New York.

Those parts of the authors' *Analytic Geometry and Principles of Algebra* which deal with analytic geometry, omitting the sections on algebra, are included in this volume. It is an excellent presentation of the subject and proves satisfactory in the classroom. The large number of practical applications gives the beginner a chance to get a real understanding of curves and their uses, and the fundamental notions of a derivative are given to him in a usable form. H. E. C.

Modern Business Arithmetic, Complete Course, by Harry A. Finney, Lecturer in Accounting, Walton School of Commerce, Chicago, and Joseph C. Brown, President, State Normal School, St. Cloud, Minn. Pages vi+488. 15x21 cm. 1916. Henry Holt & Company, New York.

The *Brief Course* by the same authors was reviewed in the December, 1916, issue. The present volume provides a year's work in the arithmetic of modern business. Many topics which have recently acquired importance because of changes that have been brought about in the organization and conduct of business are included. The problems are based on important business activities, and the methods of solution are those used in business practice. Teachers of business arithmetic should examine this book. H. E. C.